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When Does it Pay to Plow?

In view of the recent comments in the annual reports of the committees of both irrigated and unirrigated plantations, suggesting that plowing and cultivating are perhaps carried on to excess, an article reprinted in this number of the *Record* is especially pertinent. It consists of a review of the literature on the tillage of the soil.

Encountering such a conflict of opinion on the subject, M. C. Sewell undertook a complete review of all the printed information on the subject. He reached the conclusion that the prevailing theories advocating deep plowing and frequent cultivation are not founded upon experimental evidence.

It will be recalled that in a contribution to the last annual report on cultivation on unirrigated plantations, Mr. David Forbes felt that "we should question our present system of deep plowing between cane rows and hilling up after a cane growth has been far advanced." He was convinced that "in many cases both are carried to extremes, and to a large extent they have become a matter of custom or routine which is hard to get away from." Mr. Forbes recognized differences in conditions that would call for variations in handling the soil, and he acknowledged benefit to ensue from certain operations.

The report on irrigated plantations also dwelt upon the matter. Offbarring, small plowing and hilling were operations open to question according to that report.

Those who will read Mr. Sewell's review of the subject—and all who have anything to do with plowing or cultivating will find it extremely interesting—will very probably gain the idea that we should subject all of our tillage operations to experimental investigation.

The cost of measuring each step carefully, scientifically, will be small indeed, compared with the great gains that are in prospect should we learn that a few of our laborious and costly operations not only do not pay their way, but that they exact a further tax in actually reducing yields.

Regardless of how much or how little one may plow his lands, the thing to determine as expeditiously as possible is, when does it pay to plow?

The Cane Variety Census

The recent variety census, published as Circular 34, revealed some rather striking changes that have come about in the varieties of cane that have been adopted by the plantations.

With 20,616 acres planted to H 109, this variety becomes the standard cane for the irrigated districts. The rapid expansion of its area, crop by crop, is shown graphically in a chart which appears on the cover of this issue. The area of Lahaina is still far greater than that of H 109, but it is declining rapidly in favor of the seedling cane. The 1920 crop will include 25,078 acres of Lahaina against 7147 of H 109. The 1921 crop shows a remarkable difference in that Lahaina drops to 17,421 acres, and H 109 grows to 13,469.

D 1135 is also making rapid inroads upon the area of Striped Tip and Yellow Caledonia, although at the same time this Demerara seedling is losing ground in favor of H 109 in several of the irrigated districts.

Yellow Caledonia seems to hold its own in the district of heaviest rainfall, and still occupies an area of more than a hundred thousand acres.

There are eleven canes occupying more than 1000 acres each, counting the combined areas of the 1920 and 1921 crops. They are:

Yellow Caledonia	107,334 acres	Yellow Tip	4,728 acres
Lahaina	42,499 "	D 117	4,658 "
D 1135	23,510 "	Rose Bamboo	3,298 "
H 109	20,616 "	H 146	1,462 "
Striped Tip	5,604 "	Yellow Bamboo	1,357 "
Striped Mexican	4,938 "		

Tillage: A Review of the Literature.[1]*

By M. C. Sewell.

Introduction.

The largest item of expense in producing cereal and annual forage crops is tillage. The most important tillage operations are plowing and cultivation. Any reduction in the depth of plowing, frequency of plowing, or number of cultivations necessary for economic yields materially reduces the cost of raising the crop. The prevailing opinions are so conflicting regarding plowing and cultivation that a review of the literature seems desirable to determine what conclusions can be drawn from the written evidence on the subject.

Early History of Tillage.

The history of tillage begins with the earliest written records of mankind. Sculpturings on the ancient Egyptian pyramids represent the use of the scarcle,

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[1] Contribution No. 16, Agronomy Department, Kansas Agricultural Experiment Station, Manhattan, Kans. Received for publication June 23, 1919.

a man-power tillage implement of the chopping spade type. Other sculpturings, 4000 years old, depict a wooden plow drawn by animals.

One writer ascribes the origin of tillage to the wild boar and the observation of ancient races that plants flourished in ground previously rooted by wild boars (38).[2] The first tilling of the soil was no doubt practised in order to enable the husbandman to get his seed or plant into the soil. The second step in soil stirring was occasioned by the necessity of combating intruding weeds. The agriculture of Greece and Rome was founded on the theory that working of the soil was necessary because of the intractable soil and incursion of weeds. Virgil advocated good tillage. Since that period it has been believed that the soil is actually benefited by loosening and stirring (1).

The Early Philosophy of Tillage.

Very little seems to be known of agricultural development during the middle ages. Until 1731, when Jethro Tull published his "New Horse-Houghing Husbandry" (59), there had been no discussions of soil tillage since the time of Virgil. Tull, an English landlord, while traveling in southern Europe observed the tillage between vineyard rows. On returning to England he adapted the system to the row culture of cereal crops. He believed that the earth was the only food of plants; that the plant fed by taking in minute particles of earth, which were disengaged from the surface of the soil grains. Consequently, according to his theory, the more finely the soil was divided by tillage, the more numerous would be the particles that could be absorbed by the roots of plants. Insufficient tillage would leave the strong land with its natural pores too small and its artificial ones too large, while it would leave light land with its natural and artificial pores too large. As to weeds, he stated that they starve the plants by robbing them of their provision of food. Weeds never all come up in one year unless the land is often plowed. The best defence against these enemies, in his opinion, was a good summer fallow.

Tull ascribed the benefits of manures to the dissolving and crumbling effect they had on the soil. To this extent his theory was anti-Virgilian. According to the latter, land was pulverized by fire, and dung and harrows were used in place of the plow. The husbandry of England, especially along the southern coast, which was inhabited by Romans, was of this kind at the time of Tull's writing.

With the beginning of the nineteenth century, development in the science of agricultural chemistry through the work of Priestley (45), de Saussure (51), Davy (11), Boussingault (3), and Liebig (36), laid the foundation for the conception of the nutrition of plants as being based on the assimilation of certain chemical elements from the soil minerals, organic matter, water, and air. From this period the idea developed that tillage, by increasing the aeration of soil, increased oxidation of chemical compounds in the soil, rendering them more soluble in the soil solution.

Gaylord (18), of Onondaga, N. Y., writing in 1841, states that the end to be gained by tillage is the more effectual pulverization of the soil and mixing it together so as to insure the united action of the whole in the production of the crop. Tillage, he claims, enables us to change the character of the soil in relation to moisture, temperature, and fertility.

[2] Figures in parentheses refer to "Literature cited," p. 17.

At a meeting of the New York Agricultural Society at Albany in 1849, Lee (35), an editor from Augusta, Ga., presented the view that exhaustion of the soil is promoted by excessive plowing and hoeing. He believed that two-thirds of the tillage in the United States, especially in the southern States, impaired the natural fertility of the soil. He attributed this to the greater oxidation of organic matter on the tilled land and to the leaching of the soil of its soluble mineral elements.

The importance of deep tillage and subsoiling was brought to the attention of the Maine Department of Agriculture by Goodale (20) in 1860. It was his opinion that these practices allowed roots to penetrate deeply in search of food and moisture. The idea that the soil contains the necessary supplies of mineral matter and that tillage operations are capable of rendering these supplies available was discussed by Goodale (21) in 1861 before the meetings of the Maine Department of Agriculture.

Tanner (57) of Ohio, writing in 1861 of the mechanical conditions of the soil favorable for the growth of seed, states that the cultivator of the soil will find in the preparation of the land for the reception of seed his most laborious duty and that which demands his greatest judgment and skill. With heavy soil he found an early preparation advisable so that it can be thrown together in a dry state after which it remains untouched until seed time.

The cultivation of field crops and preparation of soils was discussed by Turner (60) in 1866 with reference to why plowing or cultivation of the soil is beneficial. He pointed out before the Maine Department of Agriculture that the old theory that tillage increases crop production by mixing ingredients already in the soil and presenting them more readily to roots is false. Since nine-tenths of plant substance comes from the atmosphere and since the roots of wheat extends 5 feet in depth and corn roots 10 feet, scratching the surface with plows and cultivators could be of small benefit. According to his view, the real end in plowing is to put the soil in such condition that the plant may most readily absorb energy from the sun, and the moisture and other food elements from the air and soil.

The view was presented by Sweet (55) of Maine in 1871 that an important result of tillage is the control of weeds. He quotes several experiments conducted in England in which weeds reduced the crop to a large extent.

According to Johnson (26), in an address before the Connecticut Board of Agriculture in 1877, the tendencies in most soils is towards mechanical compacting and chemical petrifaction. One of the important offices of tillage, he claimed, is to counteract these tendencies. He pointed out the effect of tillage in modifying the storage of water in the soil by changing the arrangement of the soil particles. He also recognized the necessity of different treatments for different soils.

That root pruning explains in part the beneficial results of tillage was the belief of Sturtevant (54) in 1877, as expressed to the Connecticut Board of Agriculture. Experiments in which corn plants grown in water cultures and in pot cultures were pruned, showed that pruning of the roots by checking their growth stimulated seed production. Cutlivation, however, was found injurious if carried beyond the flowering stage of the plant.

Davenport (10), in discussing the preparation of the soil for cereal crops in Maine in 1881, stated that the primary object of tillage was to stir and pulverize the surface of the soil that has been hardened and packed by rains. He believed that the finer the soil the more surface there is to hold moisture and for the action of the roots, and that a well-cultivated soil seldom suffers from drouth. When wheat followed oats Davenport advocated plowing as soon as possible after harvest, and keeping the surface clean and loose thereafter.

Under Missouri conditions, Waters (63) pointed out in 1887 that sod prevents surface washing and that excessive tillage increases it. The latter condition, he believed, is brought about by rapid oxidation and decomposition of vegetable matter induced by the circulation of air in the soil as a result of the cultivation.

An English writer, Walden (61), in 1891 advocated thorough tillage and gave as his opinion that a skillful farmer requires comparatively little extra soil stimulant in the form of dung to grow a successful crop. His belief that "implements make the best manuring" is not very far from the truth.

Up to this period, literature on tillage has given only conflicting views upon the subject. From this time, experimental results were published which gave more definite information.

Preparation of Seedbeds.

Morrow and Gardner (42) of Illinois compared in 1892 the yields of corn on seedbeds plowed at depths varying from 2 to 10 inches. Their results are given in Table 1.

TABLE 1.—YIELD OF CORN FROM SEEDBEDS PLOWED TO VARIOUS DEPTHS.

Treatment, 1888 to 1893	Yield in Bushels per Acre	Treatment, 1890	Yield in Bushels per Acre
Not plowed; disked shallow.....	56.4	Plowed 2 inches deep........	54.0
Plowed 2 inches deep...........	59.9	Plowed 5 inches deep........	57.5
Plowed 4 inches deep...........	69.4	Plowed 10 inches deep........	56.0
Plowed 6 inches deep...........	69.3		
Plowed 8 inches deep...........	71.1		

None of these plots had any cultivation after planting, except removing the weeds by scraping the surface with a sharp hoe. The soil was one easily worked. It was loose, porous to considerable depth, and had great capillary attraction. They concluded that deep stirring of the soil for a crop is unnecessary and that air, water, and the roots of corn readily find their way into the soil even if it has not been stirred.

In experiments with corn at the Indiana experiment station, Latta (32) found practically no difference in yield from plots plowed 8 inches deep as compared with 4- to 4.5-inch plowing. These results were averages of yields obtained from 1886 to 1891, excluding the year 1887, when no yield was obtained. In another experiment conducted for two years, 1891-1892, there was practically no difference in the yield from plowing 6, 8, 10, and 12 inches deep. Plowing 4 to 4.5 inches gave slightly smaller yields.

The Indiana station (33) gives the average results for four years of the plowing experiments begun by Latta in 1891. These data are presented in Table 2.

TABLE 2.—AVERAGE YIELDS OF CORN PRODUCED AT THE INDIANA STATION ON LAND PLOWED TO VARIOUS DEPTHS IN THE FOUR YEARS FROM 1891 TO 1894, INCLUSIVE.

Depth of Plowing, Inches	4	6	8	10	12	14	16
Yield in bushels per acre........	33.77	34.19	35.14	34.49	35.00	34.84	34.14

According to these averages, there was a slight increase in yield with depth of plowing up to 8 inches.

Sanborn (50), in 1892, compared different depths of plowing for wheat at the Utah experiment station. A plot was also included which had not been plowed. This plot was raw sage brush land and the sage brush was cut off level with the surface without stirring the soil. The wheat was planted with a hoe and at the same depth as in the other plots. The results are incorporated in Table 3.

TABLE 3.—AVERAGE YIELDS OF WHEAT OBTAINED IN A DEPTH-OF-PLOWING EXPERIMENT AT THE UTAH STATION.

Depth of Plowing	Average Yield per Acre for Three Years	
	Grains in Bushels	Straw in Pounds
Not plowed	8.6	1013
Plowed 4 inches deep.........	14.1	1101
Plowed 6 inches deep.........	13.3	1113
Plowed 8 inches deep.........	14.7	1117
Plowed 10 inches deep.........	14.4	1317

The unplowed plot gave the lowest yield, but there was only a slight difference in the yield from the other treatments. Similar results were secured in a later experiment (49). There was, however, an increase in yield of straw with the depth of plowing.

Merrill (39) conducted experiments in which the effect of depth of plowing on the yield of dry-land wheat was compared for five years at four different branch experiment stations in Utah and at one of them for an additional two years. The yields as reported in 1910 are given in Tables 4 and 5.

TABLE 4.—AVERAGE YIELDS OF WHEAT OBTAINED IN DEPTH-OF-PLOWING EXPERIMENTS CONDUCTED ON FOUR EXPERIMENT FARMS IN UTAH DURING THE FIVE YEARS FROM 1904 TO 1908, INCLUSIVE.

Treatment	Average Yield in Bushels per Acre			
	Juab County Farm†	Washington County Farm	Tooele County Farm	Sevier County Farm
Plowed 8 inches deep	23.3	11.6	14.7	5.3
Plowed 10 inches deep	23.4	12.0	14.9	5.8
Plowed 15 inches deep	16.9	15.2	14.8	6.8
Plowed and subsoiled 18 to 20 inches deep	15.4	15.2	16.2	6.4

† Heavy clay soil.

TABLE 5.—ANNUAL AND AVERAGE YIELDS OF WHEAT OBTAINED IN TILLAGE EXPERIMENTS ON THE WASHINGTON CO., UTAH, EXPERIMENT FARM IN 1907 AND 1908.

Treatment	Yield of Wheat in Bushels per Acre		
	1907	1908	Average
Disked, not plowed	27.9	13.9	20.9
Plowed 5 inches deep	25.0	13.3	19.1
Plowed 12 inches deep, not subsoiled	29.3	26 0	27.7
Plowed 16 inches deep, not subsoiled	33.7	21.0	27.4

In Washington County the results favor deep plowing. In all others nearly as good yields were secured from 8-inch as from deeper plowing.

In experiments conducted by G. W. Waters (62) in 1893 at the Missouri station, subsoiling did not give better yields of corn than plowing 7 inches deep.

In experiments at the New York station as cited by Waters, 6-inch plowing in one experiment gave better yields than plowing 12, 18, or 24 inches deep and nearly as high yields as plowing 30 inches deep. In still another experiment 4-, 6-, and 8-inch plowing gave about the same yields, which were somewhat better than were secured from disking alone or from 2- to 4-inch plowing.

Kraus (31) decided in 1894 that the greatest influence exerted upon the production of plants is the spacing, the second the effect of manuring, and the third the depth of plowing. These conclusions were based upon experiments at Weihenstephan, Germany, in which plants were seeded in wide and in narrow rows, with manured and unmanured treatments on both shallow and deep plowing.

Wollny (67), in publications at München, Germany, in 1895, compared six treatments of the soil in field plots 4 meters square. The experiment included two plots each of three tillage treatments—unworked, plowed 18 cm. deep, and plowed 36 cm. deep, one plot of each being fertilized and one unfertilized. The fertilizer used was guano applied at the rate of 200 gm. per plot (500 kg. per hectare). The soil was a calcareous loam containing 4.5 per cent humus and 2 per cent calcium. During the four years previous to the experiment the field

had grown potatoes and had been well fertilized. The experiment was conducted for three years, the crops grown being spring rye, maize, rape, flax, peas, sugar beets, potatoes, and horse beans. Wollny concluded that loosening of the soil increased its productiveness and this increase in a majority of the cases was considerable. The increase was relatively small for rye, peas, horse beans, and flax; and was relatively large for maize, rape, sugar beets, carrots, and potatoes. The fertilizer was most effective on the deep-plowed plots. According to Czerhati (9), cited by Wollny, the increase in yield from deep plowing for oats and barley was less than for maize. Kühn was cited as having conducted experiments in which it was found that plowing a sandy soil which contained but little humus to a depth of 45 cm. produced almost as much barley as a soil plowed only 10 cm. deep.

Later experiments by Wollny included an unworked treatment with the deep and shallow working of the soil. The results obtained did not occasion any change in the conclusions drawn from the previous work.

Tancré (56), a German investigator, advocated plowing immediately after harvest. Regarding the weathering of soils, he considered the winter as the time of crumbling; the spring as the time of solubility; and the summer as the time of fermenting of manure.

In experiments at the Kansas station (19), in 1895-6, surface plowing for corn produced 34.0 bushels and subsoiling 33.4 bushels per acre.

Shepperd and Jeffrey of the North Dakota Agricultural Experiment Station (53) reported, in 1897, the average yields of wheat for two years obtained by different methods of tillage. Plowing with a disk gang plow yielded 50 pounds less per acre than plowing with a moldboard. Subsoiling gave an increase of 39 pounds per acre, but at a much greater cost. Deep plowing (8 inches deep) produced 43 pounds per acre more than shallow plowing.

Lyon (37) investigated the effect on the corn crop of deep plowing and subsoiling in Nebraska. Of 59 replies from questionnaires sent to farmers in Nebraska operating on clay subsoil, 80 per cent favored subsoiling. Of those having a loam subsoil, 23 per cent favored subsoiling. Reports from western Nebraska, where the soil and subsoil are porous, showed that subsoiling reduced the yields. In 1896 and 1897 shallow plowing (4 in. deep) both in the spring and fall gave better yields than deep plowing (8 in. deep), but disking gave lower yields than shallow plowing.

Williams (65) obtained larger yields of corn in experiments conducted at the Ohio experiment station from 1891 to 1902 by cultivating shallow than by cultivating deep. The average yields of grain were 56.4 bushels for deep cultivation and 60.4 bushels for shallow cultivation.

Farrar and Sutton (16) reported in 1906 of different depths of plowing with disk and with moldboard plows on the yield of wheat, with fertilizer and without fertilizer in New South Wales. The average yields obtained are presented in Table 6. The moldboard plow gave the highest yields in all cases. Eight-inch

plowing gave higher yields than shallower plowing in most cases, but the difference was small, probably not enough to pay the extra cost.

TABLE 6.—AVERAGE YIELDS OF WHEAT IN BUSHELS PER ACRE WITH DIFFERENT DEPTHS OF PLOWING IN NEW SOUTH WALES.

Depth of Plowing, Inches	With Fertilizer		Without Fertilizer	
	Disk Plow	Moldboard Plow	Disk Plow	Moldboard Plow
4	9.7	14.5	9.7	13.3
6	8.6	16.3	8.5	15.4
8	10.2	16.5	10.7	14.8

Reitmair (46) in 1905 compared deep plowing (27 cm. or 10.6 in. deep) with shallow plowing (15 cm. or 5.9 in. deep) for several different crops. In all cases the deep plowing produced larger yields, the difference for oats being 27.8 bushels; beans for hay, 0.22 ton; and potatoes 6.3 bushels per acre in one instance and 32.5 bushels on a duplicate plot. Reitmair points out that there was not any essential difference in the nitrate supply of the deep-plowed field compared with the other and he could not explain the wide variation in the yields of the duplicate plots of potatoes.

Kaserer (27) at Vienna, Austria, in 1906 compared plowing with the treatment of loosening the soil without plowing, on a sandy loam soil. Three plots were worked 20 cm. (7.8 in. deep) for beets with an extirpator, while two plots were plowed 20 cm. deep and left rough over winter. The two methods of preparation were also compared for wheat, barley, and corn. There was no material difference in the nitrogen content of the plots and no material difference in yield except for corn. For this crop, the results were much in favor of deep plowing.

As an average of 40 trials during a period of three years at the experiment station at Davis, Cal., Shaw (52) found an average difference of about 8 bushels of wheat and 6 bushels of barley in favor of deep plowing as compared with shallow plowing. The effect appeared to extend to the following crop, an average difference of 8 bushels in the following crop of barley being observed.

Baring (2) states that in tillage experiments in New South Wales, subpacking does not appear to increase the yield. Subsoiling and deep plowing failed to give increased yields, subsoiling apparently resulting in lower yields. The disk plow gave slightly better returns than the moldboard plow.

Noll (44) reported in 1913 on the results of three years' tests of deep (12-inch) plowing and ordinary (7.5-inch) plowing at the Pennsylvania station. The yields of corn, oats, barley, wheat, alfalfa, clover, and timothy were compared. These crops were grown in rotation. The average yields, including more recent data as yet unpublished, but kindly furnished the writer, fail to show any advantage for the deeper plowing. The average yields for 1910-1913 are presented in Table 7.

TABLE 7.—AVERAGE YIELDS OF GRAIN IN POUNDS PER ACRE OF VARIOUS CROPS UNDER VARIOUS TILLAGE METHODS AT THE PENNSYLVANIA AGRICULTURAL EXPERIMENT STATION DURING THE FOUR YEARS FROM 1910 TO 1913.

Crop	Number of Years Grown	Yields in Pounds per Acre	
		7.5-inch Plowing	12-inch Plowing
Corn	3	4128	3957
Barley	1	835	792
Oats	2	1059	1086
Wheat	2	1240	1281
Alfalfa	3	2716	2774
Clover and timothy	2	4537	4483

The draft per square foot of cross section of the furrow was determined and was found to average 1113 pounds for the 12-inch plowing and 724 pounds for the 7.5-inch plowing.

Wright (70), in 1914, reports five years' results with plowing experiments at the Oklahoma station in which 7-inch plowing gave the highest yield. There was no difference between the yields from 7-, 8-, and 9-inch plowing. Subsoiling was unprofitable. The soil was an upland silt loam with an impervious subsoil.

Williams and Welton (66), reporting in 1915, compared the average yields for deep plowing, ordinary plowing, and subsoiling for corn, oats, wheat, and clover for a period of five years. The yields are presented in Table 8.

TABLE 8.—AVERAGE YIELDS OF VARIOUS CROPS UNDER VARIOUS TILLAGE TREATMENTS AT THE OHIO AGRICULTURAL EXPERIMENT STATION IN A 5-YEAR TEST.

Crop	Treatment		
	Plowed 7.5 Inches	Plowed 15 Inches	Subsoiled
Corn (bu.)	60.69	61.12	63.01
Oats (bu.)	45.49	43.80	45.11
Wheat (bu.)†	33.14	33.37	34.18
Clover (tons)	2.43	2.35	2.34

† Average for four years only.

The results show that there is not a consistent difference in favor of deep plowing or of subsoiling.

Cardon (6), in a report on dry-land tillage experiments at Nephi, Utah, states that there was not any material difference in yields obtained from plots plowed at depths varying from 5 to 18 inches. There were eight plots employed, four being cropped each year and four fallowed. The depths of plowing for fallow were: (1) Subsoiling 18 inches; (2) subsoiling 15 inches; (3) plowing 10 inches; and (4) plowing 5 inches. Regarding soil moisture, it was found that there was no advantage in deep plowing or subsoiling, for the moisture con-

tent of the 5-inch plowing was as high as that of any of the other deeper treatments.

Chilcott and Cole (8) concluded in 1918 that, as a general practice, no increase of yields or amelioration of conditions can be expected from subsoiling or other methods of deep tillage for the Great Plains as a whole. These conclusions are based on results of extensive experiments covering a wide range of crops, soils, and conditions, in ten different States in the Great Plains. The authors very aptly sum up the function of plowing in the following statements:

> It is mistaking or failing to recognize the purpose of plowing that leads to the belief that its efficiency increases with its depth even though that depth be extended below all practical limits of cost and effort. Plowing does not increase the water-holding capacity of the soil, nor the area in which roots may develop or from which the plants may obtain food. Plowing removes from the surface either green or dry material that may encumber it, provides a surface in which planting implements may cover the seed, and removes or delays the competition of weeds or plants other than those intended to grow, and in some cases by loosening and roughing the immediate surface, checks the run-off of rain water. All of these objects are accomplished as well by plowing to ordinary depths as by subsoiling, dynamiting, or deep tilling by any other method. There is little basis, therefore, for the expectation of increased yields from these practices, and the results of the experiments show that they have been generally ineffective.

Miller (41), in a study of the root systems of corn and the sorghums, isolated roots of these plants to a depth of over 6 feet and found the root development more extensive below the surface foot area of soil than above. From this fact, we may judge that deep plowing does not affect the depth of root penetration.

TABLE 9.—EFFECT OF DEPTH OF PLOWING ON YIELD IN A ROTATION OF CORN, OATS, AND WHEAT AT THE KANSAS EXPERIMENT STATION DURING THE SIX YEARS FROM 1913 TO 1918, INCLUSIVE.

Treatment	Average Yield in Bushels of Grain per Acre		
	Wheat	Corn	Oats*
Plowed July 15, 12 inches for wheat...........	24.6	22.1	34.7
Plowed July 15, 7 inches for wheat...........	24.2	24.0	37.6
Plowed July 15, 3 inches for wheat...........	24.9	22.9	38.2

* Average for five years, no grain yield in 1916.

Unpublished data of the Kansas Agricultural Experiment Station from the wheat seedbed rotation project do not give any appreciable differences in yields in 3-, 7-, and 12-inch plowing. These conclusions are based on the averages of six years' results. In this rotation, the wheat stubble is plowed in the fall 6 to 7 inches deep for corn, the corn stubble is disked in the spring for oats, and the oat stubble is plowed various depths for wheat. Table 9 presents the yields from this project.

The Kansas station also has eight years' results with wheat cropped continuously under different seedbed treatments. The average yields are presented in Table 10.

TABLE 10.—AVERAGE YIELDS OBTAINED FROM VARIOUS METHODS OF SEED-BED PREPARATION ON LAND CROPPED CONTINUOUSLY TO WHEAT AT THE KANSAS AGRICULTURAL EXPERIMENT STATION IN THE EIGHT YEARS FROM 1911 TO 1918, INCLUSIVE.

Treatment.	Average yield in bushels per acre.
Disked at seeding time	6.8
Plowed Sept. 15, 3 inches deep	12.7
Disked July 15, plowed Sept. 15, 7 inches deep	17.5
Disked July 15, plowed Aug. 15, 7 inches deep	18.2
Listed July 15, ridges worked down	17.5
Listed July 15, ridges split Aug. 15	17.4
Plowed July 15, 7 inches deep	20.8
Plowed Aug. 15, 7 inches deep. worked immediately	19.5
Plowed Aug. 15, 7 inches deep, not worked until Sept. 15	18.1
Plowed Sept. 15, 7 inches deep	13.5
Plowed July 15, 3 inches deep	16.4

These results show a decided benefit in the deeper early plowing (7 inches) over the shallow early plowing (3 inches) when wheat is grown continuously on the same land. Except in dry summers, the stubble on the August and September plowed plots is weedy unless it has been disked after harvest time. Moisture and nitrate determinations conducted in connection with this tillage project have led to the conclusion that early plowing is beneficial because it prevents weed growth and thus conserves available soil moisture and plant food (4).

The conclusion is drawn from the references discussed under this head that deep plowing (more than 7 inches deep) in general does not increase crop yields. The question left unsettled is the depth of plowing less than 7 inches that produces the best results and the necessary frequency of plowing that depth.

The Cultivation of Crops.

EFFECT ON SOIL MOISTURE, NITRIFICATION, AND YIELD.

Intertillage of crops has been practised because it has been considered beneficial aside from the control of weed growth. The general belief has been that cultivation conserved moisture by maintaining a soil mulch and, by aerating the soil, developed available plant food, thus promoting bacterial and chemical changes.

Sanborn (49) found in his tillage investigations in Utah in 1893-1894, that the difference in moisture between land plowed and unplowed was 0.63 per cent in favor of the plowed.

Grandeau (22), in 1894, in discussing the advantages and effects of deep cultivation in French agriculture, stated that old tillage practices result in a lighter, better aerated soil, and that the capillary capacity of the soil is increased. These results, he believed, increased the nitrifying power of the soil, maintained the humidity of the surface soil in a more favorable condition for vegetation, and made the nutritive elements available by placing the radicles of plants closely in contact with the soil particles. Deep working during the summer was found to double the amount of water contained in the soil as compared with soil not worked.

Kraus (31), in 1894, found the results of deep and shallow working of corn and beets in Germany to favor the deep working.

Miller and Brinkley (40), in 1897, reported yields of corn at the Maryland experiment station under deep and shallow cultivation. The depths were 6 to 7 inches and 2 to 3 inches. There was a gain of 2.4 bushels in favor of deep cultivation. They state that this gain was not enough to pay for the extra cost.

Wollny (69) published an article in 1897 on the influence of the mechanical working of the soil upon its productiveness. Previous experiments at München, Germany, had shown that loosening the soil made it accessible to air and more easily saturated, but the effect of a pulverized condition had not been investigated. The crops grown in this experiment were flax, red clover, lucerne, and grass mixture. Yields were obtained four different years. The first experiments conducted in pots were verified by field plots on a clay loam soil. The plants without exception attained higher production in the crumbly soil than in the pulverized. Consequently, Wollny decided that the crumb structure characterized the condition of the soil to be striven for in a rational system of agriculture.

The effect of loosening the soil upon the nourishment contained in the soil was also investigated by Wollny (69). Crumbly and pulverized soils, fertilized and unfertilized, were compared. For fertilizer a mixture of equal parts of superphosphate, calcium chloride, and Chili saltpeter was used. The data show that the action of the fertilizer on the crumbly soil is greater than on the pulverized.

In discussing farm practices that maintain the soil in a normal condition of structure, Wollny stated that tillage should take place immediately after harvesting the crop, otherwise the loose condition of the soil is lost after the crop covering is cut and the soil exposed to atmospheric precipitation.

In answer to the question of when and how often the soil should be worked, Wollny concluded as a result of one year's experimentation that fields requiring cultivation in the spring should be plowed in the fall; that although under certain conditions repeated workings of the soil in the spring were profitable, in the spring and summer land should be worked only when in a medium degree of moisture because with a higher or less degree of moisture the crumbly condition of the soil would not result.

Wollny also conducted experiments to determine the effect of hoeing upon plant production and the relation between the effect of loosening and the destruction of weeds without cultivation. He concluded that hoeing exercises a favorable effect upon plant production practised on land loosened in the fall, but that it often proved injurious in its effect when the soil was in good mechanical condition and a long dryness simultaneously prevailed.

The comparison of the hoed and the not hoed but weeded treatments proved that the production of plants was increased through the surface loosening, but that hoeing culture attains its greatest success primarily by the destruction of weeds.

The action of fertilizers was found by Wollny to increase with the depth of the tilled stratum, fertilization with the deeper degree of tillage producing the greatest yields.

In a later publication, Wollny (68) determined the properties of coherence,

adhesion, and friction of soils. The data presented by him emphasize the advantage of the crumbly condition of the soil.

Dehérain (13), working under French conditions, compared the amount of moisture collected from drainage under the condition of vegetation compared with fallow. The average yearly percolation for three years was 417 liters from the soil without cultivation and 440 liters from the soil cultivated. He concluded that loosening the soil favors the penetration of moisture.

In 1897 Shepperd and Jeffrey (53) reported for the North Dakota Agricultural Experiment Station the average yields of wheat for two years obtained by different methods of tillage. Seeding in cultivated drills 24 inches apart produced 10.2 bushels less per acre than wheat sown in the ordinary way without cultivation. On fall plowed and spring plowed ground, there existed a slight difference in favor of shallow plowing as compared with deep.

Dehérain (14, 15), in 1900, inspired by the old proverb "two ploughings are equal to an irrigation", attempted to show experimentally why this may be true. His experiments were directed mainly to determining the effect of a soil mulch in retarding the loss of water by evaporation. Moist soil was placed in vessels which were weighed at intervals to determine the loss. A soil mulch was maintained by covering the surface with dry soil or by cultivation. The differences in the loss of moisture were insignificant in most cases, and Dehérain concluded that a soil mulch has little effect in retarding evaporation. In later experiments he found that plants growing in the soil were the principal means by which water was removed. He advanced the idea that plowing and weeding were of equal value.

Williams (65) obtained larger yields of corn in experiments conducted at the Ohio Agricultural Experiment Station from 1891 to 1902 by cultivating shallow than by cultivating deep. The average yields of grain were 56.4 bushels for deep cultivation and 60.4 bushels for shallow cultivation.

Welborn (64), in 1908, compared the yield of corn and cotton grown with deep (6-inch) and with shallow cultivation at the Texas Agricultural Experiment Station. He failed to find any advantage for deep cultivation.

Knight of the Nevada station (30) compared in 1908 the effect of mulches of different depths on checking the loss of water by evaporation. Soil containers were used, and the dry earth mulch was applied to the wetted soil. The effect is shown in Table 11.

TABLE 11.—SOIL CONTAINER EXPERIMENTS WITH MULCHES.

Depth of mulch	Water loss in inches	Percentage of the total water loss
Water surface	4.68	78.0
No mulch	1.41	23.6
3-inch mulch	.88	14.6
6-inch mulch	.36	6.0
9-inch mulch	.17	2.9

In this experiment where the mulch consisted of dry soil applied to the wetted soil, the soil mulching was effective and increased in efficiency with the

depth. However, another experiment is reported by Knight in which the soil containers were irrigated and the soil mulch established by cultivation. Compared with a water surface loss of 8.49 inches, the soil surface cultivated 6 inches in depth lost 1.09 inches of water, and the uncultivated soil, 1.51 inches. In this instance, the difference in loss is not great.

Cates and Cox (7), in 1912, tabulated the results of 125 experiments carried on for six years, 1906-1911, in 28 different States. They concluded that cultivation is not beneficial to the corn plant except in the removal of weeds.

Mosier and Gustafson (43), in 1915, showed as a result of eight years' work at the Illinois Agricultural Experiment Station that killing weeds without cultivation produced a gain of 17.1 per cent or 6.7 bushels per acre over ordinary cultivation (shallow three times).

Thom and Holtz (58) found at the Washington Agricultural Experiment Station in 1914 that tillage materially affected the amount of precipitation absorbed by the soil. With a total precipitation of 9.56 inches, land in stubble absorbed 5 inches; disked stubble absorbed 6.25 inches; and stubble disked after harvest and fall plowed absorbed 7.25 inches.

Harris and Bracken (23), reporting in 1917 on the results of soil moisture studies under irrigation similar to those reported for dry farming at the Utah station, show that cultivation was more effective in conserving moisture than pulling weeds; the difference, however, was not great. The advisability of mulching with straw as compared with cultivation eight days after water is applied hinges on the question of labor. The difference in moisture content of the soil mulched with 2 inches of straw and soil cultivated 2 inches deep was 1 per cent, and between cultivating 2 inches deep and no cultivation but with weeds pulled, was 1 per cent.

Hutcheson, Hodgson, and Wolfe (25) as a result of corn cultivation experiments at Virginia Agricultural Experiment Station, 1913-1916, concluded that cultivation of corn is advantageous. Table 12 presents their average results.

TABLE 12.—AVERAGE YIELDS OF GRAIN AND FODDER OBTAINED FROM DIFFERENT METHODS OF CULTIVATING CORN AT THE VIRGINIA STATION IN THE FIVE YEARS FROM 1913 TO 1916, INCLUSIVE.

No cultivation, weeds growing		No cultivation, weeds cut with hoe		Three cultivations		Five cultivations	
Grain, bu.	Fodder, tons	Grain, bu.	Fodder, tons	Grain, bu.	Fodder, tons	Grain, bu.	Fodder, tons
8.4	0.7	49.0	1.4	59.4	1.6	58.6	1.5

Call and Sewell (4), as a result of three years' studies with soil mulches, showed in 1917 that for silt loam types of soil with Kansas conditions, the maintenance of a soil mulch had practically no effect in reducing evaporation. It was also found that nitrate development was as extensive without cultivation as with cultivation. Later results (5), 1918, showed that cultivation by preventing weed growth conserved the soil's supply of available plant food, and that too much

emphasis had been placed on tillage as related to moisture conservation and the development of plant food.

At the Kansas station, data regarding the effect of tillage on corn yields are available for the five years from 1914 to 1918, inclusive. These results are presented in Table 13.

TABLE 13.—ANNUAL AND AVERAGE YIELDS OF CORN VARIOUSLY CULTIVATED AT THE KANSAS AGRICULTURAL EXPERIMENT STATION DURING THE FIVE YEARS FROM 1914 TO 1918, INCLUSIVE.

Cultivation treatment	Yield per acre					
	1914	1915 [a]	1916 [b]	1917 [c]	1918 [d]	Average 1914-17
	Bu.	*Bu.*	*Bu.*	*Bu.*	*Lbs.*	*Bu.*
Ordinary	13.0	65.0	43.9	39.6	8,457	40.4
Ordinary and 1-horse cultivator to maintain mulch	13.4	62.0	43.3	39.5	8,000	39.5
Ordinary and 1-horse cultivator every 10 days	11.0	58.8	43.4	39.6	8,850	38.2
Not cultivated; weeds hoed by hand	9.2	65.0	45.2	35.0	7,580	38.6

[a] Average yield upland and bottom land, fall plowed.
[b] Average yield, fall plowed, spring plowed, and disked.
[c] Average yield, fall plowed and unplowed land.
[d] Silage yields in pounds. No grain yield in 1918.

As an average of the four years, 1914-17, the uncultivated plots where the weeds were removed produced practically as great yields as the cultivated plots. Apparently there was not any advantage from the point of yield in cultivating corn, except for the purpose of killing weeds. The small differences in yield are considered within the experimental error.

These various citations on intertillage and cultivation, with the exception of the writings of Grandeau (22) and Kraus (31) and the results at the Virginia Agricultural Experiment Station (25), show but little if any differences in the effect of cultivated and uncultivated treatments in regard to yields, conservation of moisture, and nitrification.

SOIL AERATION AND NITRIFICATION.

Concerning the viewpoint that it is necessary to promote oxidation in various chemical changes and furnish sufficient oxygen for bacterial activity, while it is recognized that oxygen is essential for chemical and bacterial changes in the soil, soils with natural drainage and in climates of medium or well-distributed precipitation may be of such a type texturally that they have sufficient aeration without cultivation practised for that particular purpose. Citations of experimental work proving this supposition have already been reviewed (5), but may with advantage be repeated in this article on tillage.

In 1902, King and Whitson (29) presented investigations at Wisconsin on

the effect of increasing aeration on nitrification. They bored holes in the soil and determined nitric nitrogen in the surrounding area. The data obtained did not indicate that nitrification was increased by this manner of aerating the soil.

In 1906, Day (12) attempted to determine experimentally the effect of artificial aeration of soils at the Ontario Agricultural College for wheat, barley, oats, and peas. The plants were grown in crocks in duplicate. Air was forced through the soil of one set once a day. There was not a benefit from the aeration of any of the crops except peas, which were very much benefited the first year. The effect of aeration on the peas was not as great the second year.

Russell and Appleyard (48), in 1915, reported results in England showing but little variation in the composition of atmospheric and soil air.

Leather (34) found that in the soils of India the diffusion of gases through soils at a depth of 12 to 15 inches is so efficient as to warrant the conclusion that cultivation of the surface soil is unnecessary for purposes of aeration. His investigations showed that even during the wettest weather, the volume of gas falls only to 15 to 20 per cent of the soil volume or about half that which is present during long periods of hot, dry weather.

Gainey and Metzler (17) of the Kansas Agricultural Experiment Station, in 1916, from laboratory studies of the rate of nitrification in a compacted and an uncompacted soil, found greater nitrification on the compacted soil up to the point where the moisture content reached two-thirds saturation.

We may judge from these various reports on aeration of the soil that many soils naturally have sufficient aeration for optimum bacterial and chemical activity without cultivation.

General Summary.

In general, we may conclude that the prevailing theories advocating deep plowing and frequent cultivation are not founded upon experimental evidence.

The review of tillage literature leads to the following conclusions:

(1) Plowing deeper than 7 inches has not generally resulted in an increase of crop yields.

(2) Shallow plowing may produce as great yields as deeper plowing, but the depth less than 7 inches which is best for economic production has not been determined.

(3) The question of frequency of plowing has not been answered, but it seems possible by proper rotation of crops to lessen the number of plowings.

(4) Cultivation may be necessary only to kill weeds and keep the soil in a receptive condition to absorb rainfall. Thus it is practical, except on very heavy soils, to reduce the amount of cultivation where the guiding policy is that of thorough cultivation in order to maintain a soil mulch.

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[J. A. V.]

Cooperation Between Field and Factory.*

By Horace Johnson.

I have been asked to speak to you today on the cooperation between field and factory. More failures have been brought about by the lack of cooperation than by any other cause. Cooperation in its broadest sense means working together for some common end or object. Perhaps a better definition would be "team-work." We all know that in any game, in any business, in any manufacturing enterprise, in any community work, there must be cooperation—there must be team-work. Furthermore, in order to make a complete success of an undertaking, there must be absolute team-work between the individuals in any one section; there must be team-work between all the sections in any one department; and there must be team-work, or cooperation, between each and every department that goes to make up the whole enterprise.

The object of the plantations in these Islands is to sell for profit a raw cane sugar. To that end the total operations may be divided into two departments:

1. That of field operations, which pertain to raising and harvesting the cane.
2. That of the manufacture and marketing of the raw sugar.

The field operations may be divided into two sections:

1. *The raising of sugar cane*; which can be subdivided into—
   - Plowing and preparing the fields;
   - Planting;
   - Cultivation;
   - Irrigation;
   - Fertilization.
2. *Harvesting and transporting*; which can be subdivided into—
   - Cutting;
   - Loading;
   - Transporting;
   - Weighing.

The manufacturing can be subdivided into—

First: The factory operations of expressing the juice from the cane; clarifying and concentrating the thin juice to a syrup; the further concentrating of the syrup to massecuites which are separated into sugar and molasses.

Second: The marketing of the sugar, which includes the transporting from the factory to cars or ships; the delivery to the market, and the sale of the sugar.

You field men know quite well the effect on the day's work, on the progress made, when the truckmen fail to deliver the gasoline to the caterpillar engine, and the plowing stops for an hour or so; when the ditchman turns the water into the wrong ditch, and the irrigators spend the time leaning on their hoes; when the pack train lies down in the road and the fertilizer gangs wait for fertilizer. You know the effect on the day's output in the harvesting field, the discontent

* A lecture presented at the Short Course for Plantation Men, Oct., 1919.

amongst the cutters and loaders, when the mill has a breakdown, and you don't get the empty cars back to the field; the locomotive gets off the track; a train of cars runs away; the trackmen are behind in their work of laying portable track; the flumes have to be changed, and flumes jam.

You know what effect these things have on your work, and you know how on some days there does not seem to be any cooperation or team-work anywhere, and all operations seem shot to pieces. You know and appreciate the fact that when there is cooperation in the field work, all goes well and you all endeavor to keep it so; to coordinate the work so that each operation may help and not hinder the rest.

But how can the field cooperate with the factory? It might seem that if the field raised the cane and delivered it to the factory, that it is up to the factory to make the sugar. That is true, but, nevertheless, the field can materially help the factory produce more sugar at less cost.

In order to know how this can be done, we must understand in a general way some of the operations of the factory and the conditions which limit the recovery of sugar in the process of manufacture.

In this connection, according to my observations, there is not enough desire on the part of the plantation men to know or understand the operations of the other departments with which they are not directly connected. The general attitude is "that is my work, and it is nobody else's business"; "don't butt in." Men seem to be afraid to explain their work or the reasons why certain work is carried on in a certain way. If one shows a desire to find out the reasons for certain operations, he is apt to be promptly squelched. Now, that attitude is all wrong. Unless there can be a chain of complete understanding throughout all the work, there can be no true cooperation. Any man who refuses to impart his knowledge to others, or has no desire to absorb knowledge from others, is a mighty weak link in the chain.

You are doubtless all familiar with the general process of the manufacture of raw sugar, so I will not take up time going into those details. I would like, however, to define some of the terms used in factory work, so that later on we may have a better understanding.

Cane. All that material which enters the rollers of the mill is termed cane. (It is sometimes called gross cane.) It includes all sound cane, dead cane, cane tops, field trash, dirt and water—in fact, everything that was on the car.

Cane Juice of Normal Juice. All soluble matter in the cane is called cane juice or normal juice.

Fiber. All insoluble matter in the cane is termed fiber. This includes the insoluble matter in the clean cane, in the dead cane, in the cane tops, and in the field trash, etc.

Juices. *Crusher or first mill juice* is the soluble matter extracted by the crusher or first mill.

Mixed juice is the juice which enters the boiling-house. It consists of juices extracted by all the mills, together with the maceration water.

Clarified juice is the mixed juice after being clarified by the action of lime and heat.

Syrup is the concentrated clarified juice, the concentration taking place in the evaporation.

Massecuite is the result of the further concentration of the syrup. This is done in the vacuum pans, and results in a mixture of sugar crystals and molasses. The sugar crystals and molasses are separated in centrifugal machines into the marketable raw sugar crystals and a molasses which still contains a considerable amount of sugar in solution.

The quality of the juices is defined by the terms of ° *Brix, polarization,* and *purity*.

The ° *Brix* represents the approximate percentage of soluble solids in the juice. The *polarization* gives the approximate percentage of sucrose in the juice. The *purity* of the juice shows the proportion of the polarization to the total soluble solids. Say we have a ° Brix, or total soluble solids, of 17.61. The polarization is 15.36. Then 15.36 is $\frac{15.36 \times 100}{17.61} = 87.2\%$, or the purity of the juice is 87.2. If the ° Brix is 17.61, and the polarization is 15.36, then there is $17.61 - 15.36 = 2.25\%$ of soluble impurities in the juice.

We have already stated that the cane is divided into soluble matter or juice and insoluble matter or fiber. If we find on analysis that the fiber is 12% of the cane, we then know that the cane consists of 88% juice. Suppose we find by analysis that the normal or cane juice has a ° Brix of 17.61, polarization of 15.36, purity of 87.2, the juice is 88% of the cane. It contains 15.36 polarization. Therefore the polarization of the cane (sometimes called the sucrose in the cane) is $15.36 \times 88\% = 13.52\%$. We now have a cane containing 13.52% polarization and a cane juice of 87.2 purity. This cane goes through the mill rollers, and a greater part of the juice is squeezed out. The fiber or insoluble matter goes through the rollers to the fire-room, carrying with it the balance of the cane juice. The greater the amount of fiber, the greater is the loss of juice.

Now let us assume that the mill is extracting 97% of the polarization in the cane sample just mentioned, which has a fiber content of 12%.

If, due to careless work in the harvesting field, there is an increased amount of field trash and cane tops adhering to the sound cane, so that we find that the cane has a fiber content of 14%, how much more sucrose or polarization is there lost than would be under normal conditions? If there are 1000 tons cane ground per day, and, under normal conditions, with 12% fiber, 97% extraction is obtained—

$13.52 \times 1000 = 135.2$ tons polarization in cane.

3% is lost with 12% fiber $= 4.06$ tons polarization lost in bagasse.

Loss with 14% fiber = ?

1050 tons cane @ 14% fiber contains 135.2 tons polarization = 12.876% polarization.

1000	@	12.00% =	120	tons
50	@	54.00% =	27	"
———		———	———	
1050	@	14.00% =	147	" fiber.

(Say 300 cane cars = 1050 tons cane; there are 333 lbs. field trash on each car.) Fiber in bagasse in both cases = 58.0%.

1st case: Bagasse = 20.69% cane = 206.9 tons, containing 4.06 tons polarization, or 1.96% polarization.

2nd case: Bagasse = 24.14% cane; 1050 × 24.14% = 253.47 tons bagasse. 253.47 tons bagasse containing 1.96% polarization = 4.97 tons polarization.

The extraction is then 96.32%, instead of 97.0%.

There is 0.91 ton more sucrose lost, which is equivalent to approximately $85 worth of sugar a day; $17,000 for a 200-day crop. This is one case where the field can help increase the yield of sugar at the factory.

FIELD TRASH IN CANE.

	I	II
Tons cane per day	1000 tons	1050 tons
Fiber in cane	12.00%	14.00%
Polarization in cane	13.52%	12.876%
Tons polarization in cane	135.2 tons	135.2 tons
Tons bagasse	206.9 tons @ 1.96% Pol.	253.47 tons @ 1.96% Pol.
Polarization lost in bagasse	4.06 tons	4.97 tons
Extraction	97.00%	96.32%
		Additional loss of polarization or sucrose, 0.91 ton. Available at sugar, 0.68 ton. Value @ $120: 120 × 0.68 = $81.60. For 200-day crop = $16,000 = $1.63 a ton of trash.

Another thing which vitally affects the quality of the mill and boiling-house work and the cost of production is the regularity with which the factory is run. We all know that any factory which runs continuously from Monday morning till Saturday night, will obtain a better recovery at a cheaper cost than the factory which operates on a one-shift basis only. Now, regularity and smoothness with which a factory can be operated must necessarily depend a great deal upon the condition and capacity of its equipment and the skill and attention of the operators.

Lack of equipment and breakdowns in a factory, lack of coöperation in a factory, not only react in a serious manner upon the quality of work and cost of operating the factory, but it reaches out into the field work. It backs up through the transportation system; it reaches the harvesting field directly or indirectly; affects nearly every department of the plantation. During the last few years considerable time and money have been spent in mill equipment, and every year shows increased interest, care and skill by the mill-men in the operation of their factories.

In order to run regularly, there must be an even supply of cane. No factory can do good work when it is called upon to crush 50 tons of cane for the day's

run, and slow down to 40 tons at night, and then, as it sometimes happens, runs out of cane entirely by morning. It is impossible to state the amount of loss caused by irregular, uneven crushing. It is much more than one thinks, however, unless he is familiar with factory work and has given the matter careful study. It can be stated as a fact that the fundamental basis of factory efficiency is a steady, even supply of cane, the quality being such as to comply with the normal capacity of that particular factory. This is a point which the field men must consider when coordinating their work.

When a field man is especially interested in any one field, he estimates or actually ascertains the weight of cane per acre. Then he next wants to know how the juices are running. Many times he is satisfied with the statement that the juices are good, or that they have a high density, or maybe a good purity, but not much sugar. You hear all these expressions quite commonly, but they really do not convey much meaning as to the quality of cane. Let us take the same example of cane as we previously used—a cane having 13.52% polarization, and a cane juice of 17.61° Brix, 15.36 polarization, 87.2 purity.

The *polarization of the cane* and the *purity of the juice* are the controlling factors in the quality of that cane. Either one alone does not mean much. We might have a cane of high sucrose and high purity, giving a very high yield of sugar. Another cane having the same percentage of polarization but of low purity will not yield nearly as much sugar. Again, another cane of high purity, but low percentage of polarization, will, of course, yield a smaller amount of sugar. In order to arrive at the quality of the cane, we must embody these two varying factors into one expression. The term now commonly used is the number of tons of cane required to produce a ton of sugar. This is also expressed as the quality ratio.

If a field man knows the amount of cane per acre, and then finds out from the factory the quality of that cane in terms of tons cane per ton of sugar, or the quality ratio of that cane, he can at once know the approximate yield of sugar per acre or the actual value of the field.

You have noticed that the Experiment Station, in reporting the results of their field experiments, give the weight of the cane, the quality ratio, and the tons sugar per acre. This quality ratio is determined from the analysis of juice and a formula for recovery of sugar from that juice.

$$\text{Tons cane per ton of sugar} = \frac{1.00}{0.8 \text{ poln. in juice} \left(1.4 - \dfrac{40}{\text{Purity of juice}}\right)}$$

This formula does not take into consideration variation in fiber content of the cane, nor the actual quality of the factory work. However, tables have been made from this formula, and it is therefore very simple to determine a comparative quality ratio from the juice analysis only. This table is used at many plantations for arriving at the quality of cane from the different fields. Other plantations have made up tables of their own, which take into consideration the quality of work done by that particular factory. These tables probably come closer to the actual quality of the cane than the results obtained by the H. S. P. A. tables.

Either method, however, can be used, as the results by any one method are strictly comparable.

We have previously stated that the polarization of the cane and the purity of the juice are the controlling factors in limiting the recovery of sugar. Now let us see how *much* effect the purity of the juice has on limiting the recovery of sugar. In a general sense the purity of the juice does not affect the extraction of juice by the mill. The limiting effect is in the boiling-house work.

We previously assumed a cane having 13.52% polarization and a cane juice of 87.2 purity. After clarification, this juice would have a purity of approximately 88.7. Such a cane, with good factory work, would produce a ton of sugar for each 7.83 tons of cane. 100 tons of cane would yield 12.771 tons of sugar.

(° Brix of cane, 15.50; polarization of cane, 13.52; impurities, 1.98%.

Yield of sugar, 12.771; yield of sucrose = 12.324; sucrose lost, 1.196.

$\frac{1.196}{1.98} = 51.$ 100 impurities prevents 51 sucrose from being recovered.)

Now let us assume a cane of 13.52% polarization, and a purity of juice after clarification 85.7. With the same quality of factory work, this cane will have a quality ratio of 8.03, and 100 tons of cane will yield 12.453 tons of sugar. 12.771 — 12.453 = 0.318, or 2.50% less sugar than was obtained in the first case. This loss is due to the impurities in the juice, which prevent the sugar from crystallizing. Roughly speaking, each unit of soluble impurities in the cane presents 0.50 of a unit of sugar from crystallizing. The more impurities, the greater the loss in sugar.

As cane ripens, we find less of the soluble impurities which come under the head of glucose, and an increase in the amount of polarization. Under these conditions, where we might have an unripe cane having a juice of 18.32° Brix, 15.7 polarization, and 85.7 purity, and polarization of cane 13.82%, quality ratio of 7.74, which upon further ripening would produce a juice of 18.32° Brix —16.12—88.0 purity, and assuming the same fiber as above, this cane would then have 14.19 polarization in cane, and the quality ratio would be 7.40.

7.74 tons cane @ ton sugar	= 12.920	tons sugar	@ 100 cane
7.40 " " " " "	= 13.501	"	" " " "
	0.581	"	gain = 4.50%

As a rule, an increase in the purity of the juice means an increase in the polarization of the cane; the two together mean a material increase in the yield of sugar. Barring climatic conditions, what can be done in the cultivation, in irrigation or fertilization of cane, to increase its purity? On an irrigated plantation, is it good practice to keep the water on the cane right up to harvesting time? What is the right time to take it off? In fertilization, is it good practice to put on nitrates too late in the season? What is too late? Any conditions relating to the purity of the cane juice can be studied to advantage by the field men.

With the present price of sugar, an increase in purity of one degree would mean, on a 20,000-ton crop, an increase of 400 tons of sugar, valued at $48,000.

If, due to late harvesting, the cane is overripe, or, as we say, "goes back," then we would lose sugar in the proportion as we have shown above. A drop in purity not only means that we have narrowed the limits of recovery in the boiling-house, but that we have lost some of the original sucrose as well. This can be illustrated by the following table:

Cane Juice			Poln. % Cane	Tons Cane per Ton Sugar	Sugar per 100 Cane	Gain or Loss
° Brix	Poln.	Purity				
18.00	15.84	88.0	13.94	7.52	13.30	+ 6.4%
18.00	15.66	87.0	13.78	7.67	13.04	+ 4.3%
18.00	15.48	86.0	13.62	7.83	12.77	+ 2.2%
18.00	15.30	85.0	13.46	8.00	12.50	0 0
18.00	15.12	84.0	13.30	8.16	12.25	— 2.0%
18.00	14.94	83.0	13.15	8.32	12.02	— 3.9%
18.00	14.76	82.0	12.99	8.49	11.78	— 5.8%

Prof. Dean, in one of his lectures on plant life, showed us how the plant takes in CO_2 through its leaves, water through the root system, and, by the aid of light and heat, transformed these elements into the hextoses

$$3\ CO_2 + 6\ H_2O = C_6H_{12}O_6 + 6O$$

In cane sugar we call the hextose compounds, glucose. A further reaction goes on within the plant which changes the hextose or glucose to sugar.

$$2\ C_6H_{12}O_6 = C_{12}H_{22}O_{11} + H_2O$$

glucose = cane sugar.

These actions are going on simultaneously, so that we always have glucose and sugar present in the cane. In the unripe cane there is a relatively large amount of glucose and a small amount of sugar. As the cane ripens we find less glucose and more sugar. When the cane is over-ripe or starts "going back," we find the reverse taking place—the amount of sugar decreases and the amount of glucose increases.

	Unripe Cane	Ripe Cane
Cane juice:		
° Brix	18.32	18.32
Polarization	15.7	16.12
Purity	85.7	88.0
Fiber % cane	12.0	12.0
Polarization % cane	13.82	14.19
Quality ratio	7.74	7.40
Sugar per 100 tons cane	12.920	13.501
Gain	....	0.581 ton
Gain	....	4.50%

Doubtless you have read in the September number of the *Record* the article on "The Deterioration of Cane After Cutting." The results are surprising to everyone.

According to the tests made, there is a loss in weight of 2% for each of the first three days after cutting, and from then on the loss in weight is 1 to 1.5%.

1 day old	2.0%	4 days old	7.0%
2 days "	3.9%	5 " "	8.5%
3 " "	5.5%	6 " "	9.7%

Taken by itself the loss in weight would not be material, for if at the same time there was no destruction of sucrose, the amount of available sugar would be the same. Unfortunately there is a destruction of sucrose, and to a much greater extent than we have realized. The experiments show a loss of available sugar of

1 day old	2.5%	4 days old	18.5%
2 days "	5.0%	5 " "	23.0%
3 " "	12.5%	6 " "	27.5%

Experiments were conducted with different cane varieties. The losses of D 1135 were the greatest. Then followed Lahaina, and H 109 seemed to show the least deterioration. The Experiment Station made no tests on Yellow Caledonia, but tests made at some of the plantations show that this cane lost at about the same rate as the average shown of the above-mentioned varieties.

"It is realized that the figures given are for a few deteriorations only, and that the rate of deterioration is not necessarily the same under other conditions. However, as the losses indicated by even a short delay in grinding the cane after cutting are so serious, and are corroborated by other tests made in other countries, we should make a study of this situation.

"Tests should be made on as many plantations, and under as widely varying conditions, as possible. The Experiment Station is willing to cooperate with any plantations planning to conduct such tests, and will render any assistance possible."

Just how much loss is actually sustained by the plantation is hard to estimate. We all know that in most places some of the cane is ground one day after the cutting, a part of it gets to the mill in two days, more in three days, and some in four days or longer.

As each car of cane is not sampled and analyzed separately, we might not notice the variations in the quality of the cane from the different cars. The juice is analyzed, say, in four or six-hour periods. The average sample of these periods might not vary much, while there might be big variations in the individual cars.

Now it is commonly considered that if one gets the cane to the mill within three days after cutting there is no loss. According to the tests which have been made, the loss amounts to 7.5% more than if the cane was crushed two days after cutting.

On a 20,000-ton crop this would amount to 1500 tons of sugar, at present valued at $180,000. Now, these figures seem appalling, yet there is every indication of their being at least approximately correct.

We cultivate, irrigate, fertilize an acre of cane for 500 days at a cost of, say, $150 per acre. By delay in getting that cane to the mill we can lose in three days sugar to the value of $80 an acre. We concentrate on methods of cultivation, experiment with kinds of fertilizer, to reduce costs and increase yields. Yet with three days' delay in getting the cane through the mill we can lose three-quarters of a ton of sugar per acre.

To be consistent we surely should study this phase of the plantation operations, and make every effort to reduce this possible loss.

Fertilizers and Soils.*

By S. S. Peck.

The purpose of this paper is to explain something of the nature and functions of fertilizers as applied to sugar cane. In order to understand the question of fertilizers, it is necessary to know something of the nature and peculiarities of the soil, which will be treated briefly.

It is not necessary to enlarge on the importance of the subject. Every member of a plantation staff is eager to get as much sugar per acre as possible; and more cane means more sugar, provided the extra cane is not produced at the cost of the quality of the juice. The factories are striving mightily to get more and more sugar into the bags from the cane delivered by the field men, by increasing the extraction at the mills and diminishing the losses in molasses. An increase of 2 per cent in extraction is viewed with considerable satisfaction, and certainly reflects credit on those responsible. But this 2 per cent is not all velvet; it is obtained sometimes at the cost of extra fuel, or of expensive milling machinery, of breaking rollers or new boiling-house installations, but it *pays*. Now, sugar is made in the first instance in the field. If a field produced 50 tons of cane per acre, yielding 6 tons of sugar, and the yield is increased to slightly over 51 tons with 6.12 tons of sugar, it has jumped up 2 per cent, but one would probably never notice it. But if the yield jumps up to 55 tons cane, with 6.6 tons of sugar, or a gain of 10 per cent, then the field men begin to take notice and pat themselves on their respective backs. And if the yield drops that much, then they begin to ask questions or, what is worse, have questions asked of them.

When the number of sticks of cane on an acre of land is considered, it is remarkable how a little change one way or another makes for an increase or decrease in crop. Thus: On an acre of land are 50 tons of cane with stalks averaging 8 feet in length, 1.2 inches in diameter, and weighing 12 ounces per foot or 6 pounds per stalk. If the length of each stalk is increased 10 per cent, the average length of stalk now being 8 feet 10 inches, the yield is likewise increased 10 per cent. But if the diameter is increased 10 per cent, or by twelve one-hundredths of an inch, the yield goes up 21 per cent. And if both increases transpire, the yield increases 33 per cent, or from 50 to 66 tons cane per acre. Again, if the crop is producing five sticks to the stool, and one can force or wish another stick of equal weight and size on each stool, the yield increases 27 per cent, or to 63 tons of cane. In other words, and working backwards, to get an extra 2 per cent in the field, one need only either increase the average length of the stalk from 8 to 8.16 feet, or by 2 inches (and here the importance of careful attention to the work of the cutting gang might be mentioned), or the average diameter from 1.2 to 1.212 inches; or in place of having five canes to a stool, force one stool in every ten to have six canes. It would be a hard matter to notice an extra 2 inches in the length of stalk; or that one stool in

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* Presented at the Seventeenth Annual Meeting of the Hawaiian Chemists' Association.

every ten was producing one more stalk than the other nine; and 12 thousandths of an inch increase in diameter would require very careful and painstaking observations. Yet any one of them would mean 2 per cent more sugar produced. But we are not concerned nor must we be satisfied with such slight advantages. What we must be after is: first, big crops; second, bigger crops; and third, biggest crops. We cannot all have the last, but we should aim for it, and then we can at least make a hit at the second.

The cane grows in soil. Soil is not a dead, inert mass of dirt. It is the home of millions of living organisms and the seat of constant and numberless chemical changes. There is much that we do not know about it; there is also much that we think we know, but wherein we are probably entirely wrong. Every soil presents its own peculiar problems, many of which can be answered only by the man on the job. We do know that the soil is the house, as it might be called, of the crop. And the crop, to be robust and healthy, requires that its house should be as wholesome, from a crop standpoint, as ours. It must be sanitary; well aërated; the plumbing or drainage must be efficient; it must be free of pests; and lastly, but not leastly, the larder must be well provisioned. Not only plentifully stocked, but the stuff must be of the right kind. Each crop, besides, requires its own peculiar ration. Just as a hog and a canary differ both in kind and quantity of food consumed, so do plants. But of paramount importance is the cleanliness of the quarters. All crops respond to efficient tillage, which is their house-cleaning. That is essential. If one gave an animal most liberal rations, but allowed its quarters to become filthy, one could expect nothing but disappointment in its progeny. So in the cane; no matter how well or how liberally it is fertilized, unless the soil is in good tilth, there will be no compensating returns. At the inception of experiment station work on the mainland there were many farmers who thought that all that was necessary to produce bumper crops was to get a small bag of soil—the smaller the better, as it cost less postage,—mail it to their State experiment station, where a soil doctor would analyze it and send back a recommendation for fertilizer. Then Mr. Farmer would buy a ton or so of Clover Leaf brand, or Diamond Q fertilizer, curtail his cultural operations, and think that the arduous work of harrowing or plowing could be replaced by the easier operation of scattering about some bonemeal or chemicals. It would be like one of us feeding up on lobster a la Newburg when our stomachs were not in shape to digest a milk shake.

The fertilizers or food can now be discussed. There are natural fertilizers, like stable or pen manure, the virtues of which are too well known to require repetition. Then there are the artificial fertilizers, which supply plant-food materials in a more concentrated form. The requirement of crops for nourishment is today largely supplied by such materials. Each part of human or animal food plays a definite role in the economy of the body—replaces worn-out tissues, builds up new tissues, supplies muscular energy or nerve force, etc. So in plant life, each fertilizer element or ingredient has its function. Some of the food of humans acts, not as a direct food, but as a stimulant. It might perhaps be added that much of that drank acts similarly. So it is in the plant: some fertilizers act not as direct food, and they are called indirect fertilizers. We all know that some stimulants, if used too freely, are no longer helpful. So in the

plant, an excess of these indirect fertilizers may work more harm than good. The food of humans has to go through a course of preparation in the various digestive organs to transform it into a shape fit for the body. So in the plant, the fertilizer ingredients are changed according to the need and nature of the particular crop. And to complete the comparison, the great necessity for human life is respiration; we draw in air and expel gaseous waste; the plant, too, is breathing, drawing in gases from the atmosphere and expelling what it doesn't want.

Now, what is the source of this artificial plant food or fertilizer? It was not so many years ago that plantations fertilized with nothing but bone-meal; and to this day the old plantation Oriental calls the expensive high-grade fertilizer bone-meal. It is now recognized that bone-meal alone is not a properly balanced ration for cane. It is very rich in phosphoric acid, with a far less amount of nitrogen. Numerous experiments have demonstrated that cane requires more nitrogen than phosphoric acid; the bone-meal was doing good to the extent of its nitrogen content, while most of the phosphoric acid was performing no useful service, but was nevertheless paid for. It was like feeding some children a slab of bread and honey, with lots less honey than bread. The kid simply licks off the honey and the bread is not consumed—not that in this instance the bread would not prove a better food to the infant than the honey, but he just doesn't want it; just as the cane doesn't want so much phosphoric acid but is just crazy about nitrogen.

The mixed fertilizer now applied to cane is composed of three essential elements—nitrogen, phosphoric acid, and potash.

Nitrogen. The fertilizer guarantee usually states a percentage of nitrogen, with certain proportions as nitrate, as sulfate, or as organic. Nitrate nitrogen is supplied as soda, coming from Chile, whence the name Chile saltpeter, and contains 15.5 per cent of actual nitrogen. This nitrogen is accepted as being directly available; that is, the plant takes it up directly and through its digestive processes transforms it into plant tissue or life. Not only is it used in mixed fertilizers, but it is also applied alone in extra dressings. It is very soluble in water and is not fixed by the soil, so can be applied in irrigation water. The expression "fixed" requires an explanation. Those who operate automobiles know that gasoline is freed of water by straining it through a chamois skin. The water is "fixed" (temporarily) by the chamois. Soils possess the property of fixing or holding onto certain elements or combination of elements; nitrate of soda is not so held, at least as regards the nitrogen part. For this reason a heavy rainfall after a nitrate application is liable to wash part of it below and away from the reach of the plant mouths or roots, and it will be lost.

Nitrogen as sulfate means nitrogen in sulfate of ammonia. Ordinary ammonia is a chemical combination of nitrogen with three parts of another element, hydrogen. Fourteen parts by weight of nitrogen form seventeen parts of ammonia. Ammonia is a gas, as one realizes when putting his nose over a bottle of strong ammonia water. The principal source of the gas is in the products of dry distillation, as in making coke or bone-char. The gas is led into sulfuric acid, with which it combines, forming the non-volatile sulfate of ammonia; this is recovered by evaporation and crystallization like sugar or salt.

Sulfuric acid is used because of its cheapness and the good handling properties of the resulting salt.

Organic nitrogen comes principally as the end products of the slaughter-house, as blood, tankage, or bone; or as the concentrated offal from fish industries as fish-scrap. In addition, vegetable residues like cotton-seed meal and castor pomace are valuable sources of organic nitrogen, but are rarely if ever seen here. Blood is the most concentrated form, containing up to 14 per cent of nitrogen; tankage and fish-scrap come next; while bone, as before stated, contains a small amount, generally from three to four per cent. Another product, hoof-meal, with over 10 per cent, is sometimes found in mixtures, but unless it is well prepared is not very available.

In addition to these forms of nitrogen, there is still another and very important supply. The air about us contains 80 per cent of nitrogen in the free state, which certain favored plants can make use of. Unfortunately, sugar cane is not in this category. On an average, cane is given about 150 pounds of nitrogen per acre per crop. Yet an acre of soil a foot deep contains about 6000 pounds of nitrogen in organic form, and the air above this acre contains 71,000,000 pounds, yet 150 pounds of combined nitrogen in fertilizers makes a marvelous difference in crops (sometimes). This means that the cane demands its nitrogen properly prepared, just as men and animals do, and just as most plants do. Certain plants, amongst which the more familiar are clover, alfalfa, and beans, can take their nitrogen from the air and store it in little swellings on the roots. They use this nitrogen for themselves or it can be used for another crop when the gathering crop is harvested or turned under. It is like the honey bee. The bee stores up the sweets it gathers so industriously from the flowers, and then men or a big brown bear comes along and reaps the benefit. And just as the honey will not accumulate in the hive alone without the assistance of the active little bee, so the nitrogen must be gathered from the air through activity of a living organism, in this case bacteria. Without the presence of these minute organisms these plants would, like all other plants, live on the nitrogen they find in the soil or die of nitrogen starvation. Some soils are populated with these organisms; others must be inoculated, which can be done either by introducing some soil known to be inhabited or by artificial cultures. The first is the more successful, but has the same objection as our immigration problems —some or a great many undesirables may be brought along with the desirables, and these undesirables may be not only loafers, but criminals. Again, like the busy bee, granting that the beneficial organisms are in the soil, if nitrogenous fertilizers are used, the host plant develops a lazy streak and gets its nitrogen therefrom with the least exertion on its part; very much like the bee, which, if supplied with sugar and water near the hive, may not go to the painstaking effort of working the flowers. This is a form of graft that even humans are occasionally guilty of. So if cane is planted along with one of these plants, known as leguminous plants, and nitrogenous fertilizer is applied, the chances are that instead of benefiting the cane, it is being robbed of just the amount of nitrogen gobbled up by Mr. Jack Bean or whatever legume is used.

There is yet another organism which plays a part in gathering nitrogen from the air, and it doesn't need any plant to help it either. It goes by the name

of azotobacter, which means nitrogen bacteria. These little fellows are like their cousins, however, in that they will not work unless they have to. In a field growing cane and receiving fertilizer they are rather inactive; but when a field is fallowed, and particularly when it receives an occasional cultivation during fallowing, these bacteria take nitrogen from the air and enrich the soil to an extent that is sometimes surprising; this nitrogen is in a state that becomes readily available to the cane, and explains in part the benefit obtained from resting a field.

By the term "availability" of nitrogen is meant that condition in which it can be taken up by the roots of a plant and utilized. There can be but little doubt as to the availability of nitrate nitrogen. The effect of a nitrate of soda application is quickly apparent in the appearance of the leaves of the cane. So it is generally accepted that nitrogen to be available must be in the form of nitrate of some sort. It is not the soda, since nitrate of lime does equally well, and nitrate of ammonia would be still better, but is too expensive. Nitrate of soda is not fixed or held by the soil. Sulfate of ammonia is held very firmly. If a solution of sulfate of ammonia is poured on a column of soil a foot deep and the drainage collected, no ammonia will be found therein. Under favorable conditions, ammonia is changed in the soil to a nitrate combination, by a species of bacteria. There is no need to worry about the presence of these microbes—they are in all good soils of good tilth. They do their work better under certain conditions, the principal ones being good drainage and aeration and the presence of lime. These bugs work slowly, so that the nitrate is formed gradually and not subject to waste like it is when applied directly as such, at least to a far less extent; for it must be remembered that as soon as the transformation is complete, the new combination is no longer fixed by the soil, but subject to loss by leaching, and it is also available. Organic nitrogen is practically insoluble in water, so naturally is not liable to loss by leaching, neither is it available. The nitrogen in it is transformed by a different regiment of bacteria into ammonia, which is then grabbed by the other species just referred to and changed into the nitrate form. The advantage of having several forms of nitrogen in a mixed fertilizer is now apparent. The nitrate form is at once available to the crop; by the time it is used up by the plant or by leaching, the sulfate of ammonia is being turned into nitrate and starts feeding the cane; then follows first the ammonification and then the nitrification of the organic nitrogen. It is a sort of relay banquet offered to the cane, and at the cost of but one application the nitrogen nourishment is furnished in palatable form for a long period of time. The cost of the nitrogen varies according to its origin, the nitrate being the cheapest and the organic the dearest. It might be asked, why not use only nitrate and put it on at intervals during the entire crop in the irrigation water? The pulp of the grape is a pretty good food, but the skin and seeds are rather indigestible. If one were to devour a lot of them, skins, seeds, and all, he would be getting the food value of the pulp, but would be accumulating a lot of trouble from the rest, which may crop out as indigestion or appendicitis. So in nitrate of soda: the cane takes up the nitrate but leaves a corresponding amount of soda in the soil. This soda if it accumulates does damage to the soil in proportion to the amount present. The black alkali soils

in the States owe their condition to the soda salts present. On the other hand, when sulfate of ammonia is used, the ammonia only is consumed and sulfuric acid released. Soda and sulfuric acid may be compared to the positive and negative poles of a battery, one neutralizes the other, and from the combination there is thus less danger of harming the soil. The danger from either source would arise only when large doses were given the soil, but the effect may be cumulative, and this is the reason that some plantations occasionally replace the extra nitrate dressings with one of sulfate of ammonia with very good results. One point more in regard to sulfate of ammonia; it nitrifies very much better in a soil well supplied with some form of lime, which is one reason why putting on coral sand tends to increase crop yields.

Phosphoric Acid. The two principal sources of this are bone and phosphate rock. In both the acid exists in the same combination, but seems more available in the bone probably for this reason: bone contains organic nitrogen, and when it is stirred into the soil and supplied with sufficient moisture, this starts to putrefy, which is one of the stages of ammonification already referred to. In this process certain gases are given off which help to dissolve the phosphate portion of the bone. This point is important, for it is only when in solution in the soil water that the mineral nutrients are absorbed by the root hairs of the plant. The soil is full of decaying organisms and plants, so that there is always more or less of gas being generated, depending on conditions, one of which is a correct amount of moisture; for all this decomposition is effected by living organisms, and they must have water just as do all the higher forms of animal life, or die. The gas is principally carbon dioxide, the same gas which when compressed into syphons gives such an agreeable "pep" to grape juice and other extinct drinks, and helps us to solve many difficult problems. So in the soil it helps dissolve and make available to the plant insoluble materials like bone or phosphate rock. This explains why bone is more easily available than rock, and why the latter is rendered more available if plowed under with a green crop. As a rule on these Islands, phosphoric acid is supplied in a form known as "water-soluble," which means just what it says. This form is prepared by treating phosphate rock with sulfuric acid, when there is a chemical change effected and the phosphoric acid becomes soluble in water. It is known then as superphosphate or acid phosphate. Being soluble in water it has the advantage over other forms of being well distributed in the soil. It is not carried away by drainage, being fixed very rapidly; but now, instead of being in fairly large particles, it is distributed in a very fine state on the particles of soil, and more easily attacked by the soil water and acids. An intermediate form of phosphate is that known as reverted phosphate. While not soluble in water, it is quickly dissolved by weak acids, and appears to be a very desirable form under certain conditions. Plants cannot survive in the absence of phosphoric acid, and it is just as essential to the organisms of the soil, without which there would be no crop. So whether the argument is that phosphoric acid is used as a part of the fertilizing system as food for the crop or as food for the organisms, the answer is the same. The United States is fortunate in having large deposits of phosphate rock and cheap sources of sulfuric acid.

Potash. As the name indicates, this was first obtained from the burning of wood, the ash remaining under the cooking utensils. Today the main supply is in some favored parts of Europe. It is mined principally as the chloride, but on account of better handling properties, as well as the reluctance to put any more chlorine compounds in our soil water than is already supplied by the salt therein, it has usually been purchased for Island purposes in the form of sulfate. Both salts are soluble in water, and the potash part is fixed by the soil. It is a fact that most of the Island soils are well stocked with potash, but the extent to which this is available is problematical. Large amounts are removed by the crop. The molasses from the factories, large amounts of which are shipped away, contain about 4 per cent. If an acre produces 50 tons of cane, on the basis of 2.8 parts molasses per 100 cane, this may mean 112 pounds of potash, which is already quite in excess of the 70 pounds which were formerly applied when potash was obtainable. An acre foot of soil contains from 8 to 14 thousand pounds of potash. The latter would be sufficient for 100 crops; but, as already stated, it is not certain how available it is.

In conclusion, it may be interesting to note the regular cycle which is or can be followed by the fertilizer elements. Thus phosphoric acid is applied to the soil; some of it is held there, some of it is taken up by the crop, and a very small proportion is taken out in the drainage waters and eventually finds its way to the sea. Of that taken up by the crops, some is fed to animals, the bulk of which goes into the formation of bone, and the bones are again put on the land in the form of bone-meal. Or man is the consumer and a part follows the sanitary arrangements back to the sea, where it is consumed by the finny inhabitants, which starts the cycle again through the human route or directly by application to the soil as fish-scrap. The cane takes up some which may be divided into the part which remains in the bagasse and trash, and that in the juice. The last is precipitated out during clarification, is recovered in the mud or press-cake, and goes back to the soil. The potash cycle is not so evident, as most of that consumed is voided and the return not so rapid. All vegetation contains it as a considerable proportion of its ash or mineral matter. What is contained in the cane leaves is returned to the land when the cane is burned or the trash turned under; that in the juice finds its way into the molasses and could be, and is in some places, almost entirely conserved by burning the molasses and saving the ash; or if the molasses is fermented for alcohol production, the potash is in the residue and can be recovered. If the molasses is run into the irrigation water the potash naturally finds its way back to the soil, but there are objections to putting molasses on growing cane. The closing of the European sources of potash during the war has been an incentive to investigations into possibilities of local production; the most promising of these in the United States were certain kelps on the Pacific Coast, and the brines from some salt lakes.

The nitrogen cycle is both more complicated and interesting. It is shown diagrammatically in this diagram taken from the 1909 Year Book of the U. S. Department of Agriculture.

Imagine that all the nitrogen originally in the world existed as the free nitrogen of the air, as shown in the inner circle. This is useless to most crops,

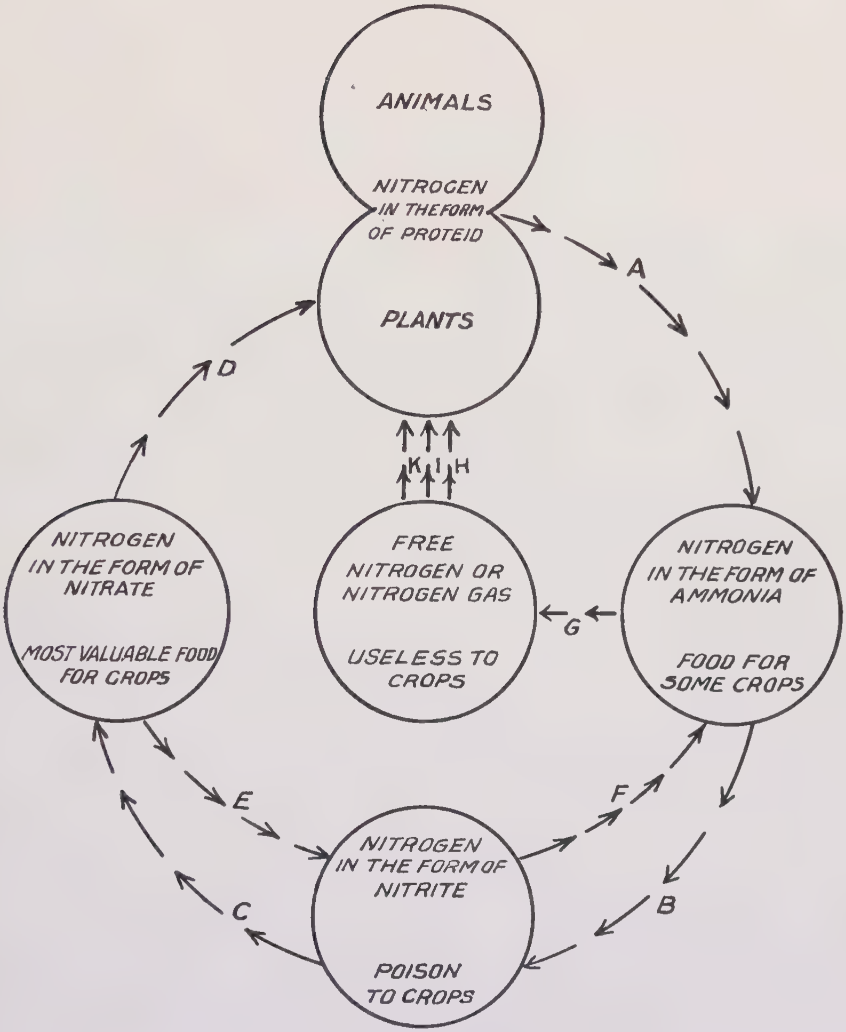


Diagram showing the nitrogen changes produced in the soil by the action of bacteria. The arrows indicate the course of the changes which various groups of bacteria may produce in the nitrogen compounds of the soil. A, action of ammonifying bacteria which change organic nitrogen to ammonia; B, action of nitrifying bacteria which change ammonia to nitrite; C, action of nitrifying bacteria which change nitrite to nitrate; D, assimilation of nitrate by green plants; E, action of denitrifying bacteria which change nitrate to nitrite; F, action of denitrifying bacteria which change nitrite to ammonia; G, action of denitrifying bacteria which change ammonia to nitrogen gas; H, action of bacteria which change nitrogen gas into proteid nitrogen; I, action of bacteria which in symbiosis with leguminous plants change nitrogen gas into proteid nitrogen; K, action of bacteria which in symbiosis with certain non-leguminous plants change nitrogen gas into proteid nitrogen.

but, as already explained, it can be transformed by the action of certain micro-organisms into a form suitable for future use by plants, this form being known as proteid. Animals eat the protein of the plants, and the upper circle is shown as a part of the protein circle. If this nitrogen-holding material is buried, be it animal or plant, it decomposes into ammonia nitrogen, following the line "A." Some plants can use it as such, but generally it suffers a further change along

line "B" into the nitrite form. This combination is poisonous to plant life. Fortunately, it does not remain long as such, nor does it accumulate in good soils, but changes along line "C" into the nitrate form where it is plant food, along line "D" back into the proteid form in plants, ready again for nourishment of animals or directly for another cycle through the series. All of the nitrogen is not conserved in this way. There exists a tribe of destructive organisms in the soil which break down what the beneficial organisms build up, and some of the nitrate nitrogen may be decomposed back through the series into free nitrogen, as indicated by lines "E," "F," and "G," or even by a short cut directly back to the form of free nitrogen. This does not occur to any extent in well-drained and well-aerated soils, and is generally the result of poor husbandry.

Finally, the question of proper fertilization of cane has not yet been completely answered. There are so many varying conditions entering, as soil, climate, water supply, variety of cane, etc., that no set rule will suffice. The plot experiments now being conducted by our Experiment Station are throwing much light on the subject, and close observation with exchange of experiences will materially assist in putting this subject on a more definite basis.

Some Results From the Use of Phosphoric Fertilizers at the Haiku Substation.*

By F. G. Krauss.

As agricultural chemists, you are familiar with the general properties and functions of phosphorous as a fertilizer constituent. It may be interesting to some of you, to have illustrated, by concrete examples, some of the remarkable results obtained from its use, in its various commercial forms as fertilizer, on a variety of agricultural crops in this Territory.

Our upland soils at Haiku, on the northern slopes of Haleakala, with an average annual rainfall of about 70 inches, are very unproductive in their virgin state to most agricultural crops other than pineapples. The natural growth on most of these lands is guava and a rank growth of Hilo grass, and the lands are quite acid. In texture they would be classed as gravelly loam. The surface soil is 12 inches in depth on an average, and the natural drainage is fairly good.

With the best of tillage and most seasonable planting, very poor results are obtained from planting corn, beans, potatoes, etc., and it is impossible to get a stand of alfalfa, although some of the ranker-growing legumes, such as pigeon peas, do fairly well.

* Presented at the Seventeenth Annual Meeting of the Hawaiian Chemists' Association.

The following analysis will give a comprehensive insight into their chemical composition:

ANALYSIS OF TYPICAL NEW ERA HOMESTEAD SOILS AND THEIR ACCOMPANYING SUBSOILS.

Haiku Substation.

A—Soil No. 591 (plot 13-14, section E, division 1): Soil that has proved best for pineapples.

B—Soil No. 593 (plot 7, section C, division 1)—Soil that has proved poorest for pineapples.

Chemical Analysis	Soil "A"		Soil "B"	
	0″-12″ Surface Soil	12″-24″ Subsoil	0″-12″ Surface Soil	12″-24″ Subsoil
Insoluble matter	34.25	40.30	41.55	37.35
Soluble silica	....	....	....	....
Potash (K_2O)	0.01	0.01	0.03	0.05
Soda (Na_2O)	0.58	0.50	0.15	0.22
Lime (CaO)	0.21	0.18	0.29	0.28
Magnesia (MgO)	0.70	1.18	0.78	0.47
Br. ox. of manganese	0.18	0.06	0.41	0.18
Peroxide of iron	34.22	33.12	35.95	36.32
Alumina (Al_2O_3)	15.55	11.20	8.43	10.95
Titanium (TiO_2)	5.02	6.01	5.00	4.05
Phosphoric acid (P_2O_5)	0.052	0.16	0.34	0.36
Sulphuric acid (SO_3)	0.36	0.44	0.29	0.22
Carbonic acid (CO_2)	....	....	....	....
Volatile matter	9.39	9.24	8.46	9.85
Nitrogen in soil	0.254	0.139	0.152	0.223
Hydroscopic moisture	2.59	2.43	2.16	3.58

From the above it will be seen that these soils are low in their content of potash and lime, in both the A and B samples, which were taken from adjacent fields, and as noted, one producing good and the other poor pineapples.

The A sample is low in phosphates, but the B sample would be classed as high in this constituent. The nitrogen content is high, as it is in most of our soils, and the iron very high, as compared with other standards.

Complete fertilizers were formulated on the basis of these analyses. The soil was first given a heavy application of lime, the caustic and hydrated forms being used equal to 2 tons of the oxide per acre, disked into the surface six inches. The complete fertilizer, made up of 4% nitrogen in equal parts of sodium nitrate and ammonium sulfate; 8% potash as sulfate; and 8% phosphate made up of equal parts super-(acid) phosphate and reverted. This was applied in the drill at the rate of 500 and 1000 pounds respectively per acre at time of planting. In very few cases were the gains in yields over the unfertilized plots sufficient to pay the cost of this high-priced fertilization. Heavy green manuring was practiced throughout the several years during which these experiments were under way,

and while the general average of our yields kept on improving, the returns were inadequate to the outlay.

In 1916 a comprehensive fertilizer experiment was undertaken on a plan essentially embodying the principle laid down in the "Triangular" scheme of fertilization. Every commercial form of the three so-called essential elements entered into our first comparative test of fertilization materials. The results were most astonishing. Only the phosphates, and these in every form used, i. e., as double super, super, as reverted, as Thomas' slag (basic slag) and as very finely ground bone meal gave us any results worth while. The lowest increase in yield from the use of 250 pounds as a minimum and 500 pounds as a maximum of either superphosphate or reverted phosphate per acre, was on Yuba cane (forage cane), which gave 80% increase. On Maui Red and Navy beans the increased yield from such fertilization has exceeded 500%, check plots yielding an average of 395 pounds prime bean seed per acre, and the fertilized plots 2100 pounds per acre. The money value represented by these yields is as $23.70 is to $126. The outlay in fertilizers in this case was 250 pounds superphosphate at $26 per ton, plus cost of application.

Innumerable experiments on corn have given us increased yields of from 200% to 400%. Potatoes have yielded 100% to 300% increase. Alfalfa could absolutely not be grown until the phosphatic fertilizers were applied. No single crop has failed to respond to even small applications of phosphoric acid, and on lands that originally failed to produce as much corn as the seed planted in the ground, have been made to produce the banner corn crop of Hawaii, a hundred bushels of shelled corn per acre.

Soil Solution.*

By Wm. Weinrich.

In reviewing the literature on soil analysis and in reading over the prevalent theories concerning the way plants are fed or sustained by what they take from the soil, there seems to me to be a lack of co-ordination between the great principles involved. At one time it was considered that if we knew what the soil contained in the line of plant food, we would be in a position to amend or supply any deficient element. Apparently this is not wholly true. There seems to be an additional phase of the matter which I believe can be explained by the study of the nature and properties of the soil solution.

Let us review the methods used in soil analysis. One method for indicating the available plant food present in the soil is that of the digestion of the soil by a strong mineral acid, usually hydrochloric, which is supposed to dissolve out of the soil about the same amount of material as the plant is supposed to use. The

* Presented at the Seventeenth Annual Meeting of the Hawaiian Chemists' Association.

other method is that of the digestion of the soil by a weak organic acid. Originally espartic acid was used, but later a one per cent solution of citric acid. Both of these acid methods have points of value and some points of doubtful value. The acid digestion methods are supposed to simulate the condition that exists around the root.

It is a well-established fact that most plants can assimilate food from the soil only through their root system, and this root system must be immersed in its soil solution. If this statement be true—and there is ample evidence to support it—it would therefore be highly desirable to analyze not only the soil, but its soil solution. What do we understand by soil solution? Let us define it. According to Cameron, "A soil solution is a natural nutrient medium from which the plants absorb the mineral constituents which have been shown to be absolutely essential to their continued existence and development."

The study of soil solution dates back quite a number of years, during which time various investigators have tried to devise methods which would give the true soil solution for chemical analysis, but most of them have failed because of the very minute amounts of the soil solution obtained and the attenuated form in which it is delivered.

Methods Involved for Extracting the Soil Solution.

Perhaps the first method that seemed promising was that of Doctor Lipman of the University of California, who subjected soil, held in a strong container, to the maximum pressure of some 53,000 pounds to the square inch. Contrary to belief, this tremendous pressure yielded but a very small amount of soil solution. An important factor, which at that time was overlooked, was that this tremendous pressure changed the rate of solubility of the various elements entering into the soil solution, such as specific gravity, surface tension, viscosity, osmotic pressure and specific conductivity; hence this method does not give the true index of the soil solution as it exists in its natural state.

Another method that at one time looked promising for obtaining a soil solution or water film from the soil particle, was that of whirling a mass of soil in a centrifugal separator. This did not prove out, as it was shown later that the force necessary to separate the water film from the soil particle was much greater than the force developed by a centrifugal going at the rate of 8000 revolutions per minute. Of course, this water film must not be confused with the capillary water which is easily separated by the method just outlined.

It was Lord Rayleigh who demonstrated mathematically that the force holding the film of moisture on the soil particle was of considerable magnitude, this order of magnitude being from 6000 to 25,000 atmospheres.

Several other methods later developed, namely, the method of drainage, the method of soil extracts, the artificial root method, and, lastly, the displacement method.

This paper wishes to emphasize the modified displacement method, the displacing material being an inert paraffine oil. Some of the earliest materials used were water and alcohol. Later Van Shutelen and Itano devised a method by which oil was used. A modification or improvement of this method was devised by Morgan of the Michigan Agricultural College, who used pressure

instead of suction for forcing the oil through the compacted soil. Morgan's method is somewhat as follows: A heavy steel cylinder, having a diameter of about 6 inches and a length of about 22 inches, is used to hold the soil. This cylinder is threaded at both ends to receive caps, the bottom cap being fitted with an outlet pipe and a heavy copper and asbestos screen to prevent the soil from passing through when the oil pressure is applied; the top cap having an inlet pipe through which the oil is delivered to the top of the soil. The inside of the cylinder is perfectly smooth and has a polished surface, for the reason that any tool marks or scratches would allow the oil to follow these as channels whereby the oil would pass through without coming into contact with the soil particle. When an extraction is to be made, the soil is tightly packed in the cylinder and the top cap screwed on. An inert paraffine oil is then applied to the top of the soil through the agency of the hydraulic pump, this hydraulic pump exerting a pressure of about 500 pounds to the square inch. What apparently takes place is that the paraffine oil is forced into the soil and wedges or cleaves the water film from the oil particle, pushing the water film ahead of itself. In the course of from 10 to 24 hours, depending upon the texture of the soil, the resulting soil solution is allowed to drain out from the bottom of this cylinder, which, to all intents and purposes, delivers a true representation of the soil solution which surrounds the soil particle. It has been demonstrated by Mr. Morgan that the various physical constants such as surface tension, viscosity, specific gravity, etc., are not in any way changed from their true state by this low-pressure method of extraction.

The essential feature of this method is that a very large percentage of soil solution present in the soil is delivered at the outlet of the cylinder. In some cases as high as 70 per cent of the soil water is extracted and rendered available for analysis, or to be used for a nutrient solution for the growth of plants. I believe the results of this method, combined with the results of our standard method of soil analysis, will give more nearly the true condition which takes place in plant growth than we have been able to obtain heretofore.

This preliminary data is presented as a possible aid to those who have soil problems, and it is hoped that this will be supplemented during the next year by actual figures from our Hawaiian soils.

How to Get Reliable Results from Experiments.*

By W. P. Alexander.

INTRODUCTION.

DEFINITION: A field experiment is a practical test in the field in an endeavor to ascertain and compare the relative value of different agricultural practices.

FUNCTION: A field experiment aims to answer specific plantation questions that demand more than observations. It should furnish data that can be used practically to increase profits as well as yields. The results of properly conducted field tests, continued over many years, are not theory, but proven facts—facts that are guide-posts to efficiency, and that eliminate all guess-work.

VALUE: A field experiment is valuable only when properly planned, correctly laid out, carefully conducted, and the data obtained accurately recorded and properly interpreted. Unless these details are thoroughly worked out, a field experiment is not only worthless, but is a dangerous thing. False results might mislead and cause great losses before the error was detected. Accuracy and extreme care are necessities of all field experimentation.

EXPERIMENT TECHNIQUE.

PLANNING AN EXPERIMENT: In the beginning one should analyze the questions asked, deciding:

(1) *The object of the experiment.* Let it be as simple as possible. Eliminate all factors that might confuse final results. During the two years or more, in which time the experiment is to run, we must not deviate from our initial purpose. Once *decided,* stick to the project without change through as many seasons as possible. The experiment must be worth while ten years from now, just as well as at the present date, if it is worth conducting at all. The curse of successful experimentation is the failure to follow an object through many years, come what may. Therefore, have the object one that will stand the test of time.

(2) *The comparisons to be made.* Let these also be as simple as possible. Follow the principle that definite results can only be obtained when the factors involved can be readily interpreted without consideration of any theory involved; that actual yields of the different treatments will be the sole method of drawing conclusions. Therefore, have as the proposed comparison some standard, proven practice against some unknown or doubtful practice. Always check up and correlate one plot treatment with another.

SELECTION OF SITE OF EXPERIMENT: If there were no variation in soil fertility, field experiments would not be a difficult task. However, there is no experimental field that has uniform conditions throughout its entire area. Select the site of an experiment, with due regard for the uncontrollable factors preventing uniformity of plots, taking into consideration: (a) Soil—chemical,

* A lecture presented at the Short Course for Plantation Men, October, 1919.

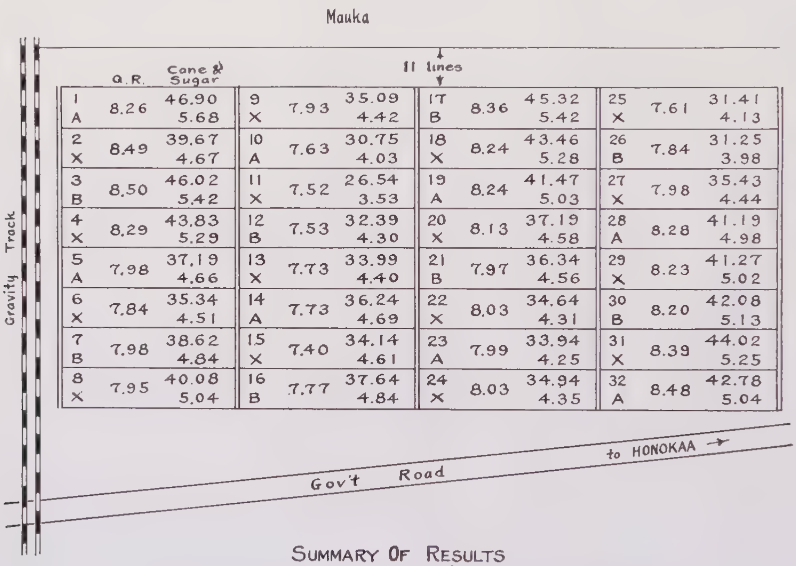
physical, and biological variations; (b) Unevenness in drainage; (c) Exposure to wind. Try and find a site where the topography is as uniform as possible. This does not mean find the most fertile spot, but find the location where all plots will be subject to the same conditions.

ARRANGEMENT OF PLOTS: It is now a recognized principle of field experiments that there be many small plots, and that they be repeated again and again, scattering the plots over the entire experimental area, until each treatment has been tried out under the varying conditions of soil fertility. The law of averages is made use of. The result is that the *repetition of plots* has partly eliminated the error due to discrepancies in soil variation, moisture changes, and wind effect.

The arrangement of these repeated plots may be done in different ways, depending on the kind of experiment, and the area given to the test.

REVERTED PHOSPHATE EXPERIMENT

PAAUHAU SUGAR PLANTATION CO. EXP. 12, 1919 Crop



SUMMARY OF RESULTS

PLOTS	No. OF PLOTS	TREATMENT	YIELD PER ACRE		
			CANE	Q.R.	SUGAR
X	16	No Reverted Phosphate	36.94	8.01	4.61
A	8	750* Reverted Phosphate	38.81	8.09	4.80
B	8	1500* Reverted Phosphate	38.71	8.04	4.81

Example of layout having "every other plot a check."

(1) *Every other plot a check.* This layout is of value, (a) when the topography is irregular, and when the point to be determined is very fine; (b) when trying to prove or disprove a practice that has long been established; (c) when we wish direct comparisons, and (d) when we have a large experimental field, and the area is not restricted.

(2) *Every third plot a check.* Advisable when, (a) area is restricted; (b) topography is even, and (c) differences between plot treatments are greater.

(3) *Series of plots.* This arrangement can be used when there is a very

MIXED FERTILIZER VS. NITRATE OF SODA

Hakalau Plantation Co. Exp. #2, 1919 Crop

Plot	Treatment	Tons p.a. Cane	Tons p.a. Sugar
1	A	38.57	4.55
2	B	39.71	4.94
3	C	42.82	5.24
4	A	37.18	4.39
5	B	39.18	4.87
6	C	32.35	5.18
7	A	38.97	4.60
8	B	41.47	5.16
9	C	43.81	5.36
10	A	36.73	4.34
11	B	40.69	5.06
12	C	41.98	5.14
13	A	37.30	4.40
14	B	38.10	4.74
15	C	40.05	4.90
16	A	35.13	4.15
17	B	39.40	4.90
18	C	38.47	4.71
19	A	37.61	4.44
20	B	33.99	4.23
21	C	37.28	4.56
22	A	33.39	3.94
23	B	35.71	4.44
24	C	41.04	5.02

Hilo side — Field Road — 3' path — Honokaa side

25' — 174'

Mauka

Field 31 A

1st ratoons, long

24 plots — each 1/10 acre consisting of 5 furrows. Each furrow = 5' wide & 174' long.

Example of layout arranging the plots in a series.

uniform field, and the experiment deals with a subject requiring the determination of relative values, as varying amounts of fertilizer. When the plots are placed in series form there must be many repetitions. When more than five plots are used to a series, the distance between plots of the same treatment becomes too great for accurate comparisons. Three or four give more satisfactory results.

(4) *Checker-board system.* This lay-out has become standard on plantations where the experimental area is of sufficient length and breadth, i. e., in the form of a square. It can be used in combination with the above arrangements of

plots. It will be seen how accuracy in plot comparisons can be obtained. Every "B" plot, for instance, is adjacent, and under approximately the same conditions as the surrounding "A," "C" and "D" plots. Under some conditions this form of experiment cannot be laid out, but in country not divided by gulches, this system gives the best results.

Mud Press Experiment

Paauhau Sugar Plantation Co. Exp. 13, 1919 Crop

Mauka

Old Gov't Road Honokaa →

Cane & Sugar

1 Discarded A	6 37.68 B 4.49	11 47.43 C 5.56	16 49.68 D 5.93	21 45.68 E 5.27	26 Discarded A
2 36.93 B 4.55	7 36.80 C 4.48	12 39.68 D 4.67	17 44.68 E 5.36	22 35.43 A 4.41	27 42.05 B 5.11
3 39.50 C 4.93	8 36.18 D 4.31	13 39.25 E 4.63	18 35.93 A 4.33	23 30.43 B 3.79	28 46.93 C 5.64
4 36.80 D 4.41	9 39.75 E 4.69	14 38.80 A 4.87	19 37.68 B 4.73	24 38.43 C 4.81	29 38.30 D 4.64
5 37.75 E 4.47	10 32.75 A 4.18	15 38.55 B 4.69	20 30.18 C 3.66	25 44.43 D 5.32	30 42.18 E 5.00

3' Path & furrow

Gov't Road To Honokaa →

Summary Of Results.

Plots	No. Of Plots	Treatment	Yield Per Acre		
			Cane	Q.R.	Sugar
A	6	No Mud Press	35.73	8.03	4.45
B	6	1 ton Mud Press	37.22	8.16	4.56
C	6	5 tons Mud Press	39.88	8.22	4.85
D	6	10 tons Mud Press	40.84	8.37	4.88
E	6	15 tons Mud Press	41.55	8.48	4.90

Example of layout using the "checker-board system."

SIZE OF PLOTS: Experience has shown that to get reliable results plots should not be smaller than 1/20 acre, nor larger than 1/4 acre. The American Society of Agronomists in 1918 asked all experiment stations, "What do you consider the ideal size of plots?" The majority favored 1/10 and 1/20-acre plots. Numerous tests have demonstrated that a plot of 1/10 acre lends itself best to conditions where sugar-cane culture is under investigation. On many plantations it is very difficult to obtain a uniform set of plots of over 1/10 acre

each. Smaller and larger plots, it has been proven, increase experimental error. In the computation of results, and the application of specific treatments, it is very convenient to have a 1/10-acre plot.

NUMBER OF ROWS TO A PLOT: This is decided by conditions met with on a plantation. Given irrigated conditions, the distance between watercourses lends itself very readily to a 1/10-acre plot composed of 8 or 10 rows consisting of two watercourses in length, or double the number of rows and one watercourse in length.

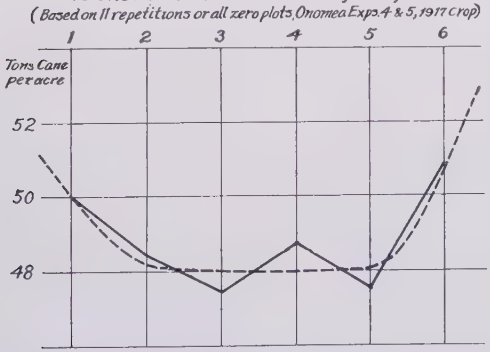
On an unirrigated plantation a plot of less than six rows is unsatisfactory. When the land is irregular, six rows make a very good standard plot of about 130 feet in length. Thus a flume line down the middle gives a distance to pack the cut cane a little less than the standard 75 feet.

It is very essential that there be an even number of lines, as it is common practice when harvesting for the cane-cutters to work in pairs and tie the cane cut from two lines in one bundle. An odd line causes much confusion.

NEED OF GUARD ROWS: The influence of the treatment of one plot upon the adjacent plot is often very great. To overcome this factor, we may use the two outside rows of each plot to protect the remainder. The following example shows what a safeguard such lines are:

A study of the effect of fertilizer applied to one line upon the cane in the adjoining one was obtained when the line weights were kept separate in Honomu Experiment No. 1 (1917 crop). A decided influence of the heavily fertilized row over the adjacent less heavily fertilized row was found varying from 2.9% to 25%, depending on the degree of difference in the fertilization between two lines.

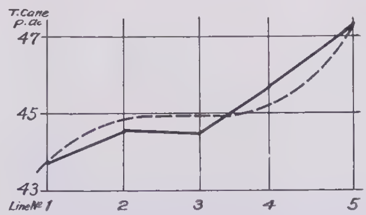
Curve Showing Effect Of Fertilizer Applied To One Row On The Cane In The Adjoining Row.
(Based on 11 repetitions or all zero plots, Onomea Exps. 4 & 5, 1917 crop)



The plots adjoining this plot in each case on both sides had 88 lbs. per acre of nitrogen more than the plot under consideration. Note the higher yields of rows 1 and 6 than the rest of the rows.

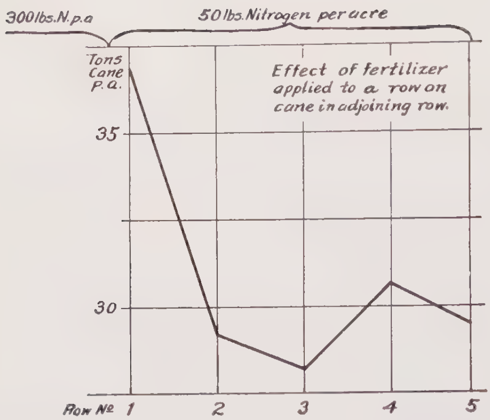
The dotted curve represents the hypothetical land value of the zero plots having an 88 pounds plot at each end.

This curve shows the effect of fertilizer applied to one line on the cane in the adjoining line. In this case the errors at both ends of the plot are in same direction.



Curve Showing Effect From Fertilizer Applied To One Plot On Cane In Adjoining Plot
(Based on Honomu Exp. 1, 1917 crop with 32 repetitions)
The plot adjoining line 1 received 500 lbs. Less of fertilizer, while the plot adjoining line 5 received 500 lbs. more.
The broken line represents the hypothetical land value of the plot.

Showing effect from fertilizer applied to one line on cane the adjoining line. The errors are in opposite directions and therefore compensated.



This figure is based on five no-fertilizer plots in Honomu Experiment 1 (1917 Crop). The plot adjoining line 1 in each case received 2500 lbs. fertilizer per acre more than the plot under consideration. The curve shows the striking effect of this fertilizer on the adjoining line, No. 1 of the next plot.

RELATION OF SITE TO HARVESTING PRACTICE: When laying out an experiment, consideration must be taken of the harvesting practice. Unless it is decided where the portable track or flume line will be located at the time of harvesting, complications result. Ease in harvesting not only facilitates the work, but lessens the chance for error. Conform to plantation routine if possible. To do this requires much thought when the experiment is laid out.

Having each plot contain straight lines which run the full length of the plot is an essential of experiment layout that must not be overlooked. There is nothing that causes more trouble when harvesting than the so-called "hapas" or half lines. They should be eliminated from all experiments.

MARKING THE EXPERIMENTAL AREA: An experiment when laid out must be so well marked and separated from the rest of the field that it will be impossible for ignorant laborers to interfere with the plot treatments. The expenditure of much time and money can be instantly lost if a gang fertilizing the surrounding field enters an experiment dealing with fertilizer practice. The following precautions should be taken:

(1) *Information.* (a) Overseers should be provided with detail maps. Full knowledge of the details of the experiment stimulates their interest so that they take a personal concern in seeing that the experiment is protected, and its welfare looked after.

(b) A point should be made to carefully explain to the laborers working in the field just where and what the "try cane" is.

(2) *Demarkation.* (a) Unirrigated Plantations:—The rear boundary can be marked by a wire fence or small stakes placed in the bottom of each row after cultivation has been completed. A small trail 2 to 3 feet wide will suffice until the cane grows large.

(b) Irrigated Plantations:—Level ditches, straight ditches, and water-courses form the natural boundaries. In both cases all experiment corners should be well marked with iron pins or good-sized fence-posts. The planting of two different varieties in an experiment so as to form a natural division of plots has been found to simplify the marking of plot boundaries.

Signs and front-line stakes are very important to so mark the different plots that there is complete information in the field as to the situation of each plot and

treatment. A map should be prepared showing layout and should include nearby roads, fences, etc., for reference. It is not enough to have the experiment well mapped on paper. The location must be well marked out in the field.

CONDUCTING AN EXPERIMENT.

UNIFORM TREATMENT OF PLOTS: Conclusions from experiments must be based with absolute certainty upon yields due to the changed condition which is artificially imposed. If the experiment deals with fertilizer, there must be a uniformity of all other agricultural practices, such as: preparation of the land for planting, selection of seed cane, planting, irrigation, and cultivation; the only variation being in the kind and the amounts of fertilizer applied.

Preparation for planting. Special care must be taken when plowing, harrowing, and mould boarding that each operation is carried out in such a manner that the plots when ready for planting differ in no respect as regards drainage, depth of plowing, and condition of the seed bed.

Selection and planting of seed. It is very important that all plots be planted with seed of identical nature. Healthy cuttings must be obtained from cane of the same age and vigor. When planting, an equal number of seed should be placed in each row. Replanting must be done until a uniform stand is secured.

Irrigation. Attention must be given to see that all plots receive water in constant quantities.

Fertilization. Only by weighing the fertilizer separately for each plot and applying it line by line can it be evenly distributed. Experienced men must be provided to make the application very uniform. A sample of all fertilizer used should be obtained and placed in an air-tight bottle to be analyzed for its formula.

Cultivation. For all cultural operations, such as hoeing and mule work, no one plot should receive advantages over another.

HARVESTING: The cutting, weighing, and sampling of the cane must be performed with the utmost care and accuracy if the results are to have any value. This requires vigilant supervision and more time than is ordinarily given to field harvesting.

Cutting. The cane from each plot must be thrown or bundled together, and so segregated that there is no opportunity for error. It is a good plan to place the brightest and most intelligent cutters on the boundary lines, where the real chances of mix-up occur.

Weighing. Where portable track is used, the cane from each plot is loaded on separate cars, and weighed at the mill. Don't fill cars so full that cane is liable to drop off. Where the practice is to weigh by bundles in the field, if the experimental area is small every bundle should be weighed. This is often impractical, and investigation has shown that weighing every third bundle gives results that are fairly accurate.

Sampling. The most satisfactory sample is one that is taken of the crusher or first-mill juice. By switching together cars from plots of like treatment, and unloading them on the carrier consecutively, there is obtained a flow of cane from

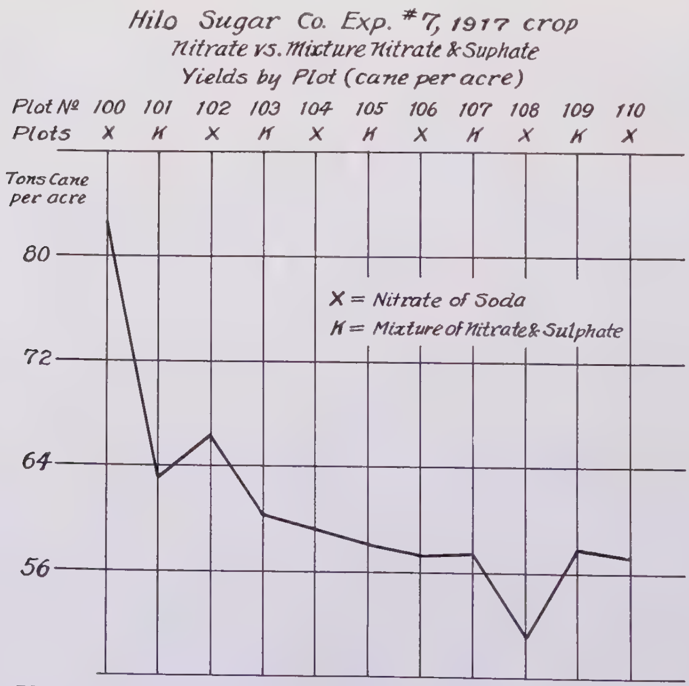
which an accurate sample can be secured by an automatic sampler. Stick samples at the best are not reliable. Despite attempts to pick stalks that form an average lot of cane from different parts of a plot, a true and very accurate test of the juice is impossible. What is obtained is only an indication of the sugar content.

RECORDING PROGRESS OF EXPERIMENT: Careful notes must be taken during the growing period of the cane on an experiment. There are many factors that may influence the growth of the cane, and unless record is made regularly during the two years it takes the crop to come to maturity, erroneous conclusions are likely to be drawn. These factors may be excessive rainfall, lack of water, uncontrolled weed growth, infestation of leaf-hopper, and the restraint they have on the welfare of the cane may be the limiting factor, obscuring completely the original plan of experiment. It is therefore essential that observations be made frequently, and notes put in permanent form for future reference.

Photographs are of special service in showing conditions of growth. Notes should be made of distance of camera from the object, height of camera, and if possible have some known comparison alongside the cane.

INTERPRETATION OF RESULTS.

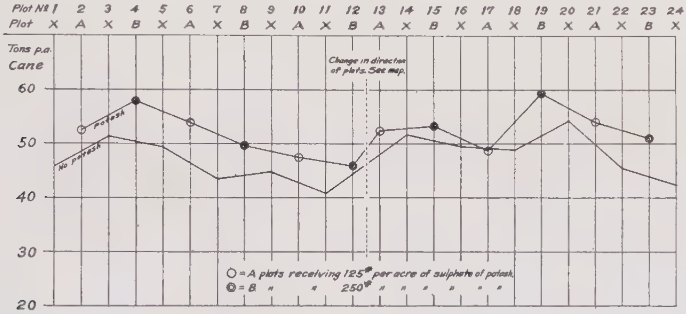
AVERAGING PLOT YIELDS: Usually by averaging the yields of the plots there can be tabulated figures showing the gain or loss due specific treatments.



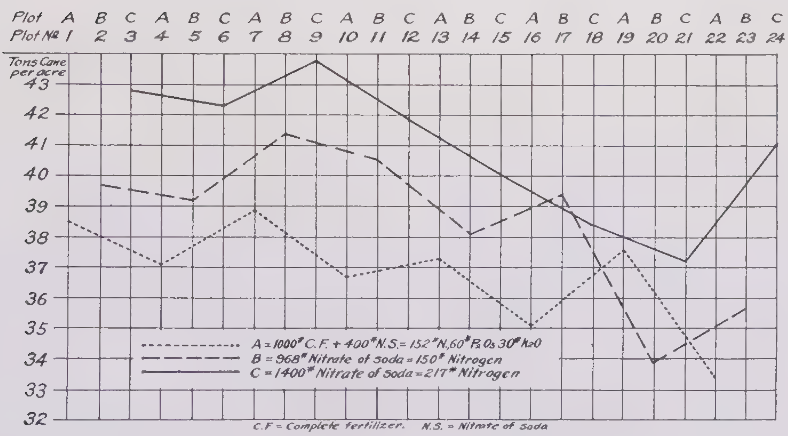
Plot curve of Hilo Sugar Co. Experiment 7 (1917 Crop), which shows the average results to be unreliable. By leaving out plot No. 100, the results are entirely reversed. The results, therefore, had to be discarded as unreliable.

STUDY OF PLOT CURVE: No results should be interpreted without a study of the individual yields of each plot. The yields may be plotted on graph paper, and, when connected, form a curve that is very helpful in pointing out consistency of the results and to locate discrepancies or possible error. The following charts are examples of the use of plot curves:

GAIN DUE TO POTASH
ONOMEA SUGAR CO. EXP. 6, 1918 crop
Curve showing cane yields per acre by plots.



MIXED FERTILIZER VS. NITRATE OF SODA
Hakalau Plantation Co. Exp. #2, 1919 Crop



These charts illustrate how consistent and accurate the results are which were obtained in these two experiments. In the above there is no doubt a decided gain for potash. In the other we are sure that nitrate of soda gave better yields throughout than mixed fertilizer.

Very erroneous results can be obtained if the distinct plot yields are disregarded, as a very high yield in one plot might distort the average yields upon which conclusions are based. An illustration is shown in Hilo Sugar Company Experiment 7 (1917 Crop) of how unreliable averages may be. The average results show a gain for the X plots of 3.84 tons cane over the K plots. When we study the plot curve it is seen that the higher yield for the X plots is largely due to the high yield of one individual plot (No. 100). By omitting this plot and substituting X plot at the oher end, the yield becomes 1.16 tons cane in favor of the K plots.

CONSIDERATION OF EXPERIMENTAL ERROR: At Waipio an experiment was laid out to study the unavoidable error in field testing. The entire area was divided into 1/40-acre plots. There was a difference in yield of 28% from two adjoining plots that were treated identically. In an experiment at Hilo Sugar Company there was a difference in yield of 24% between two similar plots separated by 30 feet.

Laying out and conducting an experiment is a long fight against this experimental error. When drawing conclusions from the data obtained from experiments the probability of experimental error must be considered. In the following table an analysis is made of experimental error and means of combatting it:

THE UNAVOIDABLE ERROR.	MEASURES TO COUNTERACT ERROR.
Varying conditions from plot to plot of— (1) Soil fertility: (a) Chemically, (b) Physically, (c) Biologically. (2) Moisture and rainfall. (3) Wind. (4) Irregularity in stand and growth.	1. Securing uniform topography. 2. Regulating the size of the plot to conform to conditions. 3. Arranging many repetitions of plots of like treatment. 4. Continuing the experiment for many seasons.

CONTROLLABLE ERROR.	MEASURES TO CONTROL ERROR.
1. Influence of one plot over adjacent plot. 2. Unevenness in: (a) preparation of field, (b) selection of seed, (c) application of fertilizer, (d) irrigation, (e) application of specific treatment. 3. Errors in harvesting cane. 4. Errors in sampling juices.	1. Guard rows. 2. Employing skilled and experienced workmen. 3. Careful supervision. 4. Well-located plots — straight and even lines. 5. Continuous sample of crusher juice from several consecutive carload lots.

CONTINUATION OF EXPERIMENT FOR MANY SEASONS: It is very important that experiments be continued from year to year. Results that are substantiated by the yields of several crops can be trusted and relied upon.

Perhaps one crop experienced excessive rainfall, or dry weather was a limiting factor. To illustrate how results are influenced by changes in growing conditions:

In Onomea Experiment No. 5 (1917 Crop) 132 lbs. of nitrogen gave a gain of 4.59 tons cane over 44 lbs. of nitrogen. For the 1919 crop the gain was only

2.05 tons cane. In the year 1916 the total rainfall was 231.19 inches; in the year 1918 the total precipitation was 304.14 inches.

Wailuku Experiment No. 1 (1917 Crop) gave a profitable gain up to 193 lbs. of nitrogen. In 1919 the addition of any nitrogen over 154 lbs. produced no increased yields. 1919 crop had to contend with a dry period when water was not abundant.

It is therefore very necessary that data be substantiated by years of the identical results due to a specific treatment. The famous Rothamsted experiments have been carried on without change for 40 years. Agricultural science has benefited greatly.

Mr. C. F. Eckart has said*: "The question of time needs be one of the most important points to be considered in forming an opinion as to the value of results. It is true that a one-crop experiment may occasionally allow one to safely draw deductions, but such instances are rare. * * * The smaller the difference in the production becomes, as manifested by the respective experiment areas, the less sure we are apt to feel that that difference was due to our changed treatment, and the less certain we should feel that this same difference would be maintained during a succeeding crop period. It becomes important, then, to repeat the experiments, not only once, but two or three times, in order to feel fully justified in condemning one practice and extolling another."

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* H. S. P. A. Bulletin No. 13, 1905.

NOTE:—Charts have previously been published in the Record.

Annual Synopsis of Mill Data, 1919.

By W. R. McAllep.

This season the Synopsis contains reports from forty-one factories. This includes all of the factories, except one, in the Association. The factories sending in data produced 98.5% of the 1919 Hawaiian crop, the largest proportion that has so far been covered by the tabulations in the Annual Synopsis.

Last year the form of the large table was changed. The columns were rearranged, and the factories were listed in the order of the amount of sugar produced, based on the average for the preceding five seasons. This plan has been followed in compiling the tables this year.

Varieties of Cane Ground.

The principal varieties of cane ground by the different factories are listed in Table No. 1. The percentage for each variety of the total crop is also shown. The 1918 averages are included for comparison. A noticeable feature of this tabulation is the large decrease in the percentage of Lahaina. All of the other columns with the exception of the one for D-1135 show an increase. H-109 shows the largest increase of any of the minor varieties. This variety is now closely pressing D-1135 for third place.

Seventy-five per cent of the tonnage included in the column "Other Varieties" is made up of the following: Striped Mexican, Louisiana Striped, H-20, H-146, Yellow Bamboo, White Bamboo, H-227, H-333, and H-16. The above are listed in the order of the tonnage ground. Each was cultivated on some plantation to the extent of one per cent or more of the crop.

Composition of Cane by Islands.

The composition of the cane by islands is shown in Table 2. Without exception, the quality is better than it was in 1918. The polarization of the cane is higher in all cases. The purity of the first mill juice is also higher, with the single exception of the Island of Kauai.

For the whole group, the quality is much better than in 1918, slightly better than in 1916, but poorer than in other years since the synopsis has been published. Improved milling and boiling house work, together with the production of a sugar of lower polarization, have made up for the difference in quality with the result that less cane was required to make a ton of sugar than in any year since 1909.

Milling.

The average extraction has increased slightly. The "milling loss," or parts sugar per hundred parts of fiber in the bagasse, is, however, a better index of the efficiency of the mill work. The loss has increased slightly.

TABLE NO. 1.

VARIETIES OF CANE.

	Lahaina	Yellow Caledonia	D 1135	Striped Tip & Yellow Tip	Rose Bamboo	D 117	H 109	Other Varieties
H. C. & S Co.	81	..	7	..	..	..	11	1
Oahu	60	6	16	..	..	..	10	8
Maui Agr.	69	1	14	..	5	..	9	2
Ewa	25	13	1	..	..	..	53	8
Pioneer	83	1	1	..	..	..	..	15
Waialua	38	16	12	..	15	2	5	12
Haw. Sug.	59	..	24	..	..	..	8	9
Olaa	..	90	10	..	..	..	..	..
Honolulu	41	53	4	..	..	..	2	..
Onomea	..	99	..	1	..	..	..	..
Kekaha	92	..	6	..	..	..	..	2
Hakalau	..	100	..	..	..	..	..	..
Hilo	..	98	1	1	..	..	..	..
McBryde	7	37	35	..	..	..	21	..
Wailuku	53	1	7	..	..	..	4	35 *
Haw. Agr.	..	74	4	..	5	..	..	17
Lihue	..	100	..	..	..	..	..	..
Waiakea	..	100	..	..	..	..	..	..
Honokaa	..	49	15	34	..	..	2	..
Laupahoehoe	..	67	3	15	..	15	..	..
Makee	1	98	..	..	..	..	..	1
Lihue, Han	..	100	..	..	..	..	..	..
Kahuku	20	74	..	..	..	..	6	..
Pepeekeo	..	96	4	..	..	..	..	..
Paauhau	..	62	17	15	..	6	..	..
Koloa	10	89	..	..	..	..	..	1
Honomu	..	99	..	..	..	1	..	..
Hawi	..	54	8	37	..	..	..	1
Hamakua	..	57	7	7	..	25	1	3
Hutchinson	..	24	1	1	74	..	..	..
Kaeleku	..	100	..	..	..	..	..	..
Kaiwiki	..	61	1	2	17	19	..	..
Kilauea	..	95	5	..	..	..	..	..
Kohala	..	49	14	37	..	..	..	..
Waianae	95	1	..	..	..	..	3	1
Waimanalo	..	100	..	..	..	..	..	..
Niulii	..	100	..	..	..	..	..	..
Halawa	..	52	4	44	..	..	..	..
Olowalu	98	..	..	..	..	..	2	..
Waimea	91	..	..	..	..	..	9	..
Kipahulu	..	100	..	..	..	..	..	..
True Average 1919	29.1	46.4	7.2	2.9	2.1	1.1	6.8	4.4
" " 1918	37.9	42.9	7.5	2.0	1.1	0.8	4.0	3.8

* Striped Mexican 34.

TABLE NO. 2.

COMPOSITION OF CANE BY ISLANDS

	Hawaii	Maui	Oahu	Kauai	Whole Group
1910					
Polarization	13.53	15.90	14.54	14.00	14.47
Percent Fiber	12.91	11.19	12.75	13.12	12.39
Purity 1st Mill Juice....	88.52	91.60	88.12	88.25	88.90
1911					
Polarization	12.91	15.45	14.45	13.51	13.99
Percent Fiber	13.27	11.79	12.92	13.26	12.85
Purity 1st Mill Juice....	88.15	91.57	88.20	87.46	88.83
1912					
Polarization	13.30	16.00	14.38	14.06	14.34
Percent Fiber	13.53	11.53	12.62	12.59	12.67
Purity 1st Mill Juice....	88.40	91.13	88.46	88.30	89.04
1913					
Polarization	13.22	15.56	14.21	13.70	14.05
Percent Fiber	13.74	11.73	12.75	12.50	12.85
Purity 1st Mill Juice....	88.47	91.11	88.20	88.12	89.02
1914					
Polarization	12.75	15.16	14.23	13.62	13.78
Percent Fiber	13.62	11.59	12.44	12.75	12.74
Purity 1st Mill Juice....	88.22	91.02	88.11	87.51	88.71
1915					
Polarization	12.61	15.23	14.29	14.09	13.77
Percent Fiber	13.00	11.44	12.77	12.46	12.51
Purity 1st Mill Juice....	87.86	90.48	87.27	86.99	88.24
1916					
Polarization	12.54	14.62	13.74	13.26	13.45
Percent Fiber	13.22	12.22	12.51	12.86	12.74
Purity 1st Mill Juice....	87.56	89.41	87.15	86.26	87.70
1917					
Polarization	13.31	15.43	13.55	13.13	13.76
Percent Fiber	13.23	11.67	12.25	12.89	12.62
Purity 1st Mill Juice....	88.11	90.69	86.86	86.70	88.02
1918					
Polarization	11.88	14.25	13.50	12.54	12.97
Percent Fiber	13.35	11.53	12.23	12.84	12.50
Purity 1st Mill Juice....	87.27	88.62	86.93	85.88	87.18
1919					
Polarization	12.74	15.12	14.24	13.52	13.74
Percent Fiber	13.07	11.74	12.14	12.61	12.49
Purity 1st Mill Juice....	87.54	88.81	87.00	85.82	87.34

The increased milling loss would lead to the conclusion that the work of the mills was hardly equal to that of last year, were it not for two factors, unavoidable in a report of this kind. First, the figures for the mill work this year represent 97.2% of the total crop against 95.1% last year. The increment has been from factories doing work considerably below the average. If data from these factories had been included in last year's calculations, the figures for milling loss for the two seasons would have been practically the same. Second, more reliable, though less favorable figures are now being reported from a few of the factories that were formerly under inadequate chemical control. Though the influence of these factors on the averages is not large, it is sufficient to justify the conclusion that there has been some improvement in the average milling work during the past year.

Table No. 3 shows the factories arranged according to milling loss. 60% of them report a lower figure than for last year.

The improvement at some of the factories ranking high in the list has been particularly noticeable. Maui Agricultural Company has again established a record for milling loss, extraction ratio and extraction, the latter averaging 99.05 for the season. Onomea also passed previous records in milling loss. A third factory, Hawaiian Commercial and Sugar Company, passed previous records in extraction, obtaining for the season an average of 98.99.

Pepeekeo established a new record in milling loss, extraction ratio, and extraction for an eleven roller mill, finishing the season with an average extraction of 97.96. This factory reported better than 98 extraction for eleven consecutive weeks. Honomu, similarly equipped, reported better than 98 extraction for ten consecutive weeks. The results obtained at these two factories indicate that a better quality of work than has generally been considered practicable, can be obtained with the shorter trains.

Olaa, Hawaiian Agricultural Company, Laupahoehoe and Waiakea have also materially improved their standing in Table No. 3. Ewa, McBryde, Hawaiian Sugar, Waialua, Pioneer and Makee have each dropped several points in their relative rank.

During the preceding two seasons there was a tendency to use slightly less maceration water. This year more maceration has been used, and the high point reached in 1918 has been passed.

The moisture content of the bagasse is lower this season than has previously been reported. The average is over one per cent better than last year. Eighty per cent of the factories report an improvement in this respect.

Clarification.

The increase in purity from mixed juice to syrup was less satisfactory than in previous years. The purity of the mixed juice was 0.3 higher than last year, but due to the smaller increase in purity, the syrup was 0.08 lower. The syrup purity was, in fact, the lowest in recent years. The smaller increase in purity has been general, only eleven factories reporting a larger increase than a year ago. It is possible that the clarification has received less attention during the past year than formerly on account of the greater amount of attention that has

TABLE NO. 3.—MILLING RESULTS.

Showing the Rank of the Factories on the Basis of Milling Loss.

Factory	Milling Loss	Extraction Ratio	Extraction	Equipment
1. Maui Agr......	1.28	0.08	99.05	K(2),21RM66
2. Onomea	1.39	0.11	98.58	2RC60,S54,12RM66
3. H. C. & S. Co...	1.53	0.09	98.99	K(4),2RC78(2),S72(2),12RM78(2)
4. Waimea	1.54	0.12	98.70	2RC48,12RM42
5. Hakalau	1.75	0.13	98.31	2RC54,12RM9-60,3-66
6. Hilo	1.88	0.14	98.03	K,2RC60,12RM66
7. Pepeekeo	2.06	0.16	97.96	2RC54,9RM60
8. Wailuku	2.13	0.15	97.95	K,2RC72,12RM78
9. Ewa	2.20	0.16	98.17	K(2),20RM78
10. Paauhau	2.34	0.19	97.43	2RC60,12RM66
11. Olaa	2.41	0.20	97.32	K,S72,12RM78
12. Honomu	2.65	0.20	97.61	2RC60,9RM60
13. Koloa	2.69	0.21	97.07	K,2RC60,12RM66
14. Kilauea	2.71	0.24	97.05	K,S,3RC60,9RM60
15. Waianae	2.74	0.19	97.42	K,12RM60
16. McBryde	2.75	0.21	97.40	K,S54,9RM84
17. Haw. Agr......	2.79	0.22	97.01	3RC60,12RM66
18. Laupahoehoe ..	2.82	0.21	97.22	K(2),11RM60
19. Kahuku	2.91	0.24	96.78	3RC60,S54,9RM72
20. Lihue	2.96	0.22	96.99	K,2RC72,12RM78
21. Honokaa	3.03	0.26	96.64	K(2),14RM2-60,12-66
22. Haw. Sug......	3.04	0.20	97.66	K,2RC72,S72,12RM78
23. Waialua	3.06	0.20	97.41	K(2),14RM78
24. Honolulu	3.09	0.22	97.28	K(2),S54,11RM78
25. Oahu	3.26	0.22	97.41	K(4),S72,14RM78,12RM78
26. Kekaha	3.28	0.23	97.19	2RC54,9RM60
27. Pioneer	3.38	0.22	97.45	K,2RC60,S54,12RM72
28. Hutchinson	3.76	0.29	96.01	2RC60,9RM60
29. Waiakea	3.81	0.29	96.13	K(2),S42,11RM60
30. Lihue, Han.....	4.05	0.31	95.77	K,2RC72,9RM78
31. Kaeleku	4.16	0.38	94.65	K(2),11RM2-54,9-60
32. Kohala	4.19	0.32	96.15	K(2),S42,11RM60
33. Kaiwiki	4.39	0.33	95.81	K(2),11RM60
34. Olowalu	5.05	0.37	95.14	K,3RC48,9RM48
35. Hawi	5.25	0.38	95.16	K(3),3RC48,12RM3-48,9-54,S42,9RM54
36. Hamakua	5.29	0.41	94.45	K,2RC60,9RM60
37. Makee	5.90	0.46	94.23	K(2),9RM72
38. Halawa	8.74	0.70	90.79	K,2RC60,6RM50
39. Kipahulu	10.73	0.79	88.85	K,5RM3-42,2-54

been given to boiling and the handling of low grades. The clarification has a large influence on the final yield of sugar, and this important department should not be neglected.

The amount of lime used per ton of cane has increased, the increase being approximately in proportion to the increase in soluble solids per ton of cane.

Filter Pressing.

The tendency toward lower polarization of the press cake continues this year. Compared with last year, a lower weight of cake per cent cane, and a smaller loss of sugar per cent polarization of cane have been reported.

Evaporation.

The brix of the syrup, though not as high as in 1916, was higher than during the 1917 and 1918 seasons. While the problems in connection with the production of better refining sugar were being solved, the brix of the syrup was lowered. This was undesirable from the standpoint of heat economy, and was in most cases unnecessary. Many factories producing sugar of good grain now evaporate their syrup to a high density. The present average, 62.42, leaves considerable room for improvement. It can be increased several degrees without interfering with the production of good refining sugar.

The amount of water per ton of cane, evaporated in the multiple effects was the largest so far reported.

Commercial Sugar.

The polarization of the commercial sugar has been reduced to approximately the point it was in 1915 and 1916, before the size of the grain was increased.

A greater proportion of the sugar than in previous seasons was above the standard for size of grain.

Final Molasses.

A year ago a very gratifying decrease in the gravity purity, amounting to 0.96, was obtained. This year the molasses was reduced to 37.95 gravity purity, a point 1.12 below last year's average. The improvement has been general, only nine factories reporting a higher gravity purity than a year ago.

The figure 37.95 is the average purity of the molasses resulting from 86% of the total crop.

In order to calculate the value of the improvement in the low grade work it is necessary to estimate the gravity purities of the syrup and sugar from the reported apparent purities. Data covering a number of years from the factories determining both sucrose and polarization indicate that on the average it is necessary to add 0.8 to the apparent purity of the syrup and 0.3 to the apparent purity of the sugar to convert them to gravity purities. These corrections, added to the apparent purities, give 86.5 and 97.6 as the gravity purity of the syrup

and sugar. Applying the s. j. m. formula, we obtain the figure 91.82 for the theoretical recovery of sucrose % sucrose in the syrup. If, however, the gravity purity of the molasses had been 39.07 as it was in 1918, instead of 37.95, the recovery would be reduced to 91.43. Assuming that the actual recovery would be in proportion to these figures, the improvement in handling the low grade products has resulted in a yield of over 2,500 tons of sugar above what would have been obtained had the work been of the same quality as that of 1918. This amount of sugar is worth on the plantations at $120 per ton, more than $300,000.

On the same basis the gain over 1917 amounts to approximately 5000 tons worth over $600,000.

The attention now being given to this part of the work will without doubt result in further improvement.

Java is the only other country from which comparative data are available. The latest figures are those for the 1918 crop. The average for all the factories was 36.9. The average for the factories using the defecation process, similar to that used in Hawaii, was 37.2.

Gravity Solids and Sucrose Balance.

An increased number of factories have reported their results on the more reliable basis of true sucrose, as well as on polarization. The gravity solids and sucrose balances of the factories so reporting appear in Table No 4. In calculating these balances when the per cent of suspended solids in the mixed juice has not been determined, it has been estimated at 0.25%.

Boiling House Recovery.

Notwithstanding the fact that the purity of the syrup was lower than in recent years, the polarization recovered per cent polarization of the mixed juice is higher than in any year during the last ten except 1915. The recovery per cent polarization of the cane is higher than in any year for which figures are available.

A comparison of the polarization obtained per cent polarization in the syrup, with the estimated available sucrose appears in Table No. 5.

This table is largely a check on the chemical control. The results in the last column are only approximately exact, for it is necessary to make certain assumptions, the details of which are given in the footnote under the table. Examination of the figures for several years indicates that when the gravity purity of the molasses has been reported, the variation due to these assumptions is probably not over plus or minus one per cent.

When the figure for recovery on available is 101 or over, there are probably errors in the chemical control. Figures below 99 may be due to errors in the control. In this case there is, however, strong probability of an unrecorded loss.

For the factories that report these data, the more reliable figures based on true sucrose and gravity solids are given in Table No. 6. Except for the possibility of solids not sugar being volatilized during the boiling process, there

TABLE NO. 4.

GRAVITY SOLIDS AND SUCROSE BALANCES.

Factory	Gravity Solids per 100 Gravity Solids in Mixed Juice				Sucrose per 100 Sucrose in Mixed Juice			
	Press Cake	Commercial Sugar	Final Molasses	Undetermined	Press Cake	Commercial Sugar	Final Molasses	Undetermined
H. C. & S. Co.	4.5	80.4	12.3	2.8	0.2	92.4	5.8	1.6
Oahu	3.3	80.7	12.6	3.4	0.2	93.0	5.4	1.4
Maui Agr.	3.7	80.1	15.8	0.4	0.3	91.7	7.2	0.8
Pioneer	2.8	79.9	14.1	3.2	0.1	92.2	6.3	1.4
Waialua	6.8	75.0	15.7	2.5	0.1	89.9	7.5	2.5
Haw. Sug.	2.8	77.8	16.8	2.6	0.3	90.2	7.9	1.6
Onomea	4.5	80.0	14.1	1.4	0.1	92.7	5.9	1.3
Hakalau	4.4	79.8	12.8	3.0	0.2	92.8	5.5	1.5
Hilo	4.5	78.9	13.9	2.7	0.2	92.5	5.9	1.4
Wailuku	3.7	78.2	16.2	1.9	0.3	91.9	7.2	0.6
Haw. Agr.	4.1	79.5	15.7	0.7	0.1	91.2	7.2	1.5
Honokaa	5.3	71.6	22.9	0.2	0.2	88.2	10.7	0.9
Pepeekeo	5.0	78.0	13.2	3.8	0.1	92.0	5.5	2.4
Paauhau	5.1	77.0	17.3	0.6	0.3	91.5	7.8	0.4
Honomu	5.0	79.2	14.0	1.8	0.3	92.6	5.8	1.3
Hutchinson	3.2	78.6	13.3	4.9	0.1	90.9	6.4	2.6
Kilauea	3.7	67.9	24.1	4.3	0.3	84.3	12.4	3.0
Kohala	5.3	77.4	13.5	3.8	0.2	92.6	6.3	0.9

TABLE NO. 5.

APPARENT BOILING HOUSE RECOVERY.

Comparing percent. available sucrose in the syrup (calculated by formula) with percent. polarization actually obtained.

Factory	Available *	Obtained	Recovery on Available
H. C. & S. Co.	93.06	93.34	100.3
Oahu	93.00	94.05	101.1
Maui Agr.	93.03	91.96 †	98.8
Ewa	91.68	92.06	100.4
Pioneer	92.37	92.24	99.9
Waialua	92.12	90.33	98.1
Haw. Sug.	91.03	91.09	100.1
Olaa	92.11	90.50	98.3
Onomea	93.75	93.12	99.3
Kekaha	91.55	90.95	99.3
Hakalau	93.12	93.04	99.9
Hilo	93.65	92.63	98.9
McBryde	89.75	88.67	98.8
Wailuku	91.71	92.67	101.0
Haw Agr.	93.16	91.67	98.4
Lihue	89.72	89.08	99.3
Waiakea	90.19	88.08	97.7
Honokaa	90.06	88.30	98.0
Laupahoehoe	93.11	94.02	101.0
Makee	88.31	87.59	99.2
Lihue, Han.	90.84	89.14	98.1
Kahuku	88.54	87.43	98.7
Pepeekeo	93.41	92.28	98.8
Paauhau	91.83	92.16	100.4
Koloa	87.83	87.08	99.1
Honomu	93.70	93.17	99.4
Hawi	92.38	87.93	95.2
Hamakua	89.77	91.07	101.4
Hutchinson	91.26	91.47	100.2
Kaeleku	85.04	87.94	103.4
Kaiwiki	91.71	93.07	101.5
Kilauea	85.72	85.42	99.7
Kohala	91.62	93.50	102.1
Waianae	88.71	87.03	98.1
Halawa	92.54	85.05	91.9
Olowalu	87.36	84.25	96.4
Waimea	91.66	88.81	96.9
Kipahulu	91.49	85.55	93.5

* In order to calculate the available sucrose it is necessary to estimate the gravity purity of the syrup and sugar. Data from factories determining both apparent and gravity purities indicate that the average correction necessary is the addition of 0.8 to the apparent purity of the syrup and 0.3 to the apparent purity of the sugar. When the moisture in the sugar has not been reported 1% has been taken. 38 has been used when the gravity purity of the molasses has not been reported.

† Sucrose.

TABLE NO. 6.

TRUE BOILING HOUSE RECOVERY.

Comparing percent. sucrose available and recovered.

Factory	Available	Obtained	% Recovery on Available
H. C. & S. Co.	93.06	92.59	99.5
Oahu	93.11	93.19	100.1
Maui Agr.	93.03	91.98	98.9
Pioneer	92.30	92.29	100.0
Waialua	92.27	89.99	97.5
Haw. Sug.	91.11	90.47	99.3
Onomea	93.96	92.79	98.8
Hakalau	93.31	92.99	99.7
Hilo	93.21	92.69	99.4
Wailuku	91.85	92.18	100.4
Haw. Agr.	93.21	91.29	97.9
Honokaa	89.62	88.38	98.6
Pepeekeo	93.39	92.09	98.6
Paauhau	92.05	91.78	99.7
Honomu	93.68	92.88	99.1
Hutchinson	91.41	90.99	99.5
Kilauea	85.90	84.55	98.4
Kohala	91.42	92.79	101.5

would appear to be no reason why the reported per cent sucrose recovered on available should exceed 100.

On account of the attention now being given to the low grade work it is of interest to compare the quantity of molasses produced with the theoretical amount. For the factories reporting sucrose and gravity solids this comparison is given in Table No. 7. Two values may be used for the theoretical amount of molasses. Both are given in the table. The first column is the commonly used figure. This is based on the assumption that the solids in the syrup, less those recovered in the sugar should appear in the molasses. The figures in the second column are based on somewhat different reasoning. The recovery indicated by the s. j. m. formula is subtracted from the sucrose and solids in the syrup and the remainder taken as the theoretical amount of molasses.

Two-thirds of the factories listed in Table 7 failed to account for as much as 90% of the theoretical amount of molasses. Without more definite information it is hard to account for the discrepancy. It is true that the solids in the molasses are a small proportion of the total entering the boiling house and that an error in the brix would make a considerable difference in the calculated amount of molasses. With hydrometers of the precision of those now available, there should hardly be a constant error of over 0.1 degree in the brix. A calculation shows that this error would amount to about 5% of the calculated amount of molasses, much less than the discrepancy shown by many of the factories. Undoubtedly

TABLE NO. 7.

PERCENT. MOLASSES PRODUCED ON THEORETICAL.

	Assuming Theoretical Solids in Molasses as Solids in Syrup Less Solids Recovered in Sugar	Assuming Theoretical Solids in Molasses as Solids in Syrup Less Solids in "Available" Sugar
H. C. & S. Co.	81.7	84.1
Oahu	78.8	78.8
Maui Agr.	97.3	102.9
Pioneer	81.5	82.3
Waialua	86.5	97.0
Haw. Sug.	86.3	88.8
Onomea	91.3	98.2
Hakalau	81.0	82.5
Hilo	84.0	86.0
Wailuku	89.7	88.3
Haw. Agr.	95.6	106.9
Honokaa	99.0	103.4
Pepeekeo	77.4	82.9
Paauhau	96.7	98.0
Honomu	88.6	92.4
Hutchinson	73.1	74.7
Kilauea	84.9	88.4
Kohala	78.0	73.4

also, some volatilization of solids takes place, though to what extent this occurs we have little information.

Factory Efficiency.

The standing of the factories according to efficiency is shown in Table No. 8. The arbitrary standard used for comparison may be expressed as a factory grinding the same cane, obtaining the same increase in purity from mixed juice to syrup, and producing sugar of the same analysis, but obtaining 100% extraction, reducing the final molasses to 30 gravity purity, and having no losses other than molasses. This standard is the same as that used a year ago.

Factories reporting a recovery of 101% or more on available (Table No. 5) have been omitted from this tabulation.

Losses In Manufacture.

The loss in molasses, the largest of these losses, is now somewhat larger than it was half a dozen years ago when figures comparable with the present were first compiled. This is not due to poorer work, but to lower juice purities. Had it not been for improvements in the boiling house work this loss would now be considerably larger than the present figures. The attention now being given to the low grade work will reduce this figure provided the juices do not

TABLE NO. 8.

FACTORY EFFICIENCY.

Showing the comparative standing of the plantations on the basis of the entire factory work.

No.	Factory	Total Recovery		Factory Efficiency
		Calculated	Obtained	
1	Onomea	94.85	91.73	96.71
2	Ewa	93.26	90.15	96.67
3	H. C. & S. Co	95.47	92.25	96.63
4	Hakalau	94.60	91.28	96.49
5	Honomu	94.73	90.68	95.72
6	Pepeekeo	94.48	90.28	95.55
7	Hilo	94.84	90.61	95.54
8	Maui Agr	95.16	90.84 †	95.46
9	Paauhau	93.83	89.46	95.34
10	Pioneer	94.30	89.77	95.20
11	Haw. Sug	93.98	88.63	94.31
12	Kekaha	94.28	88.03	93.37
13	Haw. Agr	95.36	88.87	93.19
14	Lihue	92.41	86.10	93.17
15	Hutchinson	94.18	87.74	93.16
16	Kahuku	90.80	84.46	93.02
17	Waimea	94.10	87.50	92.99
18	Waialua	94.53	87.88	92.97
19	Olaa	94.48	87.80	92.93
20	McBryde	92.97	86.27	92.79
21	Koloa	91.44	84.31	92.20
22	Honokaa	92.46	85.16	92.10
23	Lihue, Han	92.85	85.09	91.64
24	Kilauea	90.78	82.69	91.09
25	Waianae	92.63	84.37	91.08
26	Waiakea	94.00	84.49	89.88
27	Makee	91.93	82.22	89.44
28	Hawi	94.41	83.30	88.23
29	Olowalu	92.29	79.94	86.62
30	Halawa	94.55	77.15	81.60
31	Kipahulu	93.75	75.14	80.15

† Sucrose.

show further decrease in purity. An opportunity to reduce this loss lies in obtaining a greater increase in purity from mixed juice to syrup.

Second in size is the loss in bagasse. This has been reduced from a point as high if not higher than the loss in molasses till it is now less than 40% of the latter figure. There is still room for improvement, since many of the factories are far behind the leaders in this respect.

The smallest of the determined losses is that in press cake. The amount of press cake handled has increased from year to year on account of the more efficient mill work and better settling equipment. The polarization has been

reduced but on account of the increased quantity of cake handled, the loss has not changed greatly in recent years.

During the past ten years the total losses have been reduced from 15.54 to 11.43. The real improvement has been greater than the difference between these figures would indicate. The losses have been reduced notwithstanding a steady decrease in the purity of the juice of the cane, which would tend to increase them. Also, the figure 15.54 represents the losses of some two-thirds of the factories only, the others not being under sufficiently complete chemical control at that time to report such data.

The undetermined loss has also usually been reduced from year to year. This year, however, the undetermined is somewhat higher—1.27, which is some 45% of the loss in bagasse. There is of course some question as to what extent this loss is real and to what extent it is due to discrepancies in the control. With the high quality of work now being done this figure is of sufficient magnitude to receive careful investigation to the end that any real losses that are included in it may be found and if possible stopped.

A summary of the losses is given in Table No. 9.

The calculations and tables in this synopsis have been made almost entirely by Mr. Brodie.

TABLE NO. 9.

SUMMARY OF LOSSES.

FACTORY	POUNDS POLARIZATION PER TON OF CANE						POLARIZATION PER 100 CANE						POLARIZATION PER 100 POLARIZATION OF CANE						Syrup Purity	FACTORY
	Bagasse	Press Cake	Molasses	Other Known	Undetermined	TOTAL	Bagasse	Press Cake	Molasses	Other Known	Undetermined	TOTAL	Bagasse	Press Cake	Molasses	Other Known	Undetermined	TOTAL		
H. C. & S. Co.	3.2	0.4	18.8	...	2.4	24.8	0.16	0.02	0.94	...	0.12	1.24	1.01	0.15	5.84	...	0.74	7.74	87.98	H. C. & S.
Oahu	7.6	0.6	15.6	...	1.2	25.0*	0.38	0.03	0.78	...	0.06	1.25*	2.59	0.20	5.35	...	0.43	8.57*	86.5	Oahu.
Maui Agr.	3.0	0.8	22.2	...	2.6	28.6†	0.15	0.04	1.11	...	0.13	1.43†	0.95	0.27	7.08	...	0.86	9.16†	88.09	Maui Agr.
Ewa	5.2	0.8	20.6	...	1.2	27.8	0.26	0.04	1.03	...	0.06	1.39	1.83	0.26	7.34	...	0.43	9.86	84.28	Ewa.
Pioneer	7.6	0.4	18.6	0.4	3.8	30.8	0.38	0.02	0.93	0.02	0.19	1.54	2.55	0.13	6.19	0.16	1.21	10.24	85.85	Pioneer.
Waialua	7.6	0.4	22.0	...	6.2	36.2	0.38	0.02	1.10	...	0.31	1.81	2.59	0.13	7.34	...	2.07	12.13	86.7	Waialua.
Haw. Sug.	7.0	1.0	23.4	...	2.8	34.2	0.35	0.05	1.17	...	0.14	1.71	2.34	0.36	7.74	...	0.93	11.37	85.56	Haw. Sug.
Olaa	6.4	0.8	21.6	...	0.8	29.6	0.32	0.04	1.08	...	0.04	1.48	2.68	0.30	8.93	...	0.29	12.20	86.5	Olaa.
Honolulu	7.8	0.4	24.8	...	...	...	0.39	0.02	1.24	...	...	...	2.72	0.14	8.75	...	....	....	87.22	Honolulu.
Onomea	3.6	0.2	14.6	...	2.2	20.6	0.18	0.01	0.73	...	0.11	1.03	1.42	0.07	5.89	...	0.89	8.27	86.9	Onomea.
Kekaha	8.0	1.2	23.2	...	2.0	34.4	0.40	0.06	1.16	...	0.10	1.72	2.81	0.40	8.06	...	0.70	11.97	85.95	Kekaha.
Hakalau	4.6	0.6	14.6	...	3.6	23.4	0.23	0.03	0.73	...	0.18	1.17	1.69	0.21	5.44	...	1.39	8.73	86.1	Hakalau.
Hilo	5.2	0.6	15.0	...	3.8	24.6	0.26	0.03	0.75	...	0.19	1.23	1.97	0.22	5.72	...	1.48	9.39	87.04	Hilo.
McBryde	7.0	0.2	28.2	...	1.2	36.6	0.35	0.01	1.41	...	0.06	1.83	2.60	0.11	10.55	...	0.47	13.73	83.96	McBryde.
Wailuku	5.8	0.8	20.0	...	0.2	26.8*	0.29	0.04	1.00	...	0.01	1.34*	2.05	0.27	7.10	...	0.07	9.49*	84.8	Wailuku.
Haw. Agr.	7.4	0.2	18.0	...	2.4	28.0	0.37	0.01	0.90	...	0.12	1.40	2.99	0.07	7.09	...	0.98	11.13	87.68	Haw. Agr.
Lihue	8.0	0.8	...	...	28.0	36.8	0.40	0.04	...	...	1.40	1.84	3.01	0.33	....	...	10.56	13.90	82.9	Lihue.
Waiakea	10.0	0.6	...	...	29.6	40.2	0.50	0.03	...	...	1.48	2.01	3.87	0.20	....	...	11.44	15.51	85.54	Waiakea.
Honokaa	7.8	0.4	24.0	...	2.0	34.2	0.39	0.02	1.20	...	0.10	1.71	3.36	0.19	10.38	...	0.91	14.84	83.11	Honokaa.
Laupahoehoe	7.4	0.4	14.6	...	0.6	23.0*	0.37	0.02	0.73	...	0.03	1.15*	2.78	0.15	5.57	...	0.23	8.73*	87.89	Laupahoehoe.
Makee	14.6	1.0	26.8	...	2.8	45.2	0.73	0.05	1.34	...	0.14	2.26	5.77	0.37	10.56	...	1.09	17.79	82.50	Makee.
Lihue-Han.	10.6	0.8	...	...	26.2	37.6	0.53	0.04	...	...	1.31	1.88	4.23	0.31	....	...	10.37	14.91	83.6	Lihue-Han.
Kahuku	7.6	0.4	26.2	...	2.8	37.0	0.38	0.02	1.31	...	0.14	1.85	3.22	0.17	10.95	...	1.19	15.53	80.68	Kahuku.
Pepeekeo	5.2	0.4	14.0	...	5.6	25.2	0.26	0.02	0.70	...	0.28	1.26	2.04	0.12	5.41	...	2.15	9.72	86.05	Pepeekeo.
Paauhau	6.4	0.8	19.0	...	0.0	26.2	0.32	0.04	0.95	...	0.00	1.31	2.57	0.35	7.61	...	0.00	10.53	85.15	Paauhau.
Koloa	7.6	0.6	27.8	...	4.8	40.8	0.38	0.03	1.39	...	0.24	2.04	2.93	0.25	10.69	...	1.82	15.69	81.4	Koloa.
Honomu	6.4	0.8	15.4	...	2.4	25.0	0.32	0.04	0.77	...	0.12	1.25	2.39	0.28	5.72	...	0.93	9.32	86.7	Honomu.
Hawi	13.4	1.2	...	...	31.6	46.2	0.67	0.06	...	...	1.58	2.31	4.84	0.42	....	...	11.43	16.69	86.09	Hawi.
Hamakua	14.2	0.2	11.6	...	10.0	36.0*	0.71	0.01	0.58	...	0.50	1.80*	5.55	0.09	4.54	...	3.88	14.06*	84.5	Hamakua.
Hutchinson	10.2	0.2	16.0	...	5.0	31.4	0.51	0.01	0.80	...	0.25	1.57	3.99	0.09	6.21	...	1.97	12.26	86.2	Hutchinson.
Kaeleku	11.8	1.2	...	...	24.8	37.8*	0.59	0.06	...	...	1.24	1.89*	5.35	0.54	....	...	11.35	17.24*	81.82	Kaeleku.
Kaiwiki	11.2	0.6	...	...	17.8	29.6*	0.56	0.03	...	...	0.89	1.48*	4.19	0.24	....	...	6.62	11.05*	85.65	Kaiwiki.
Kilauea	6.6	0.6	27.4	...	4.2	38.8	0.33	0.03	1.37	...	0.21	1.94	2.95	0.25	12.24	...	1.87	17.31	80.7	Kilauea.
Kohala	10.0	0.6	16.0	...	0.4	27.0*	0.50	0.03	0.80	...	0.02	1.35*	3.85	0.20	6.13	...	0.11	10.29*	85.6	Kohala.
Waianae	7.4	1.4	...	...	36.2	45.0	0.37	0.07	...	...	1.81	2.25	2.58	0.47	....	...	12.58	15.63	83.36	Waianae.
Waimanalo	...	1.6	...	...	...	...	...	0.08	...	...	...	...	....	...	....	...	....	....	....	Waimanalo.
Niulii	24.0	1.2	...	...	...	...	1.20	0.06	...	...	...	...	....	...	....	...	....	....	87.5	Niulii.
Halawa	23.0	0.2	...	...	34.0	57.2	1.15	0.01	...	...	1.70	2.86	9.21	0.07	....	...	13.56	22.84	85.93	Halawa.
Olowalu	13.4	0.8	14.8	...	26.6	55.6	0.67	0.04	0.74	...	1.33	2.78	4.86	0.25	5.33	...	9.62	20.06	82.59	Olowalu.
Waimea	3.4	0.4	...	...	28.4	32.2	0.17	0.02	...	...	1.42	1.61	1.30	0.18	....	...	11.02	12.50	85.57	Waimea.
Kipahulu	30.2	2.8	...	...	34.4	67.4	1.51	0.14	...	...	1.72	3.37	11.15	1.02	....	...	12.69	24.86	85.83	Kipahulu.

* A comparison of the available sucrose in the juice with the amount recovered in the boiling house indicates that there is probably an error in some of the results reported from this factory.

† Sucrose.

ANNUAL SYNOPSIS OF MILL DATA---SHOWING RESULTS FROM 41 HAWAIIAN FACTORIES FOR CROP OF 1919

Factory	Factory No.	Milling Plant (Sizes in Inches)	CANE Polarization	CANE % Fiber	CANE Tons per ton commercial sugar	CANE Tons ground per hour	CANE Tonnage ratio
H. C. & S. Co.	6	K(4),2RC78(2),S72(2),12RM78(2)	16.05	10.64	6.49	96.51	1.37
Oahu	20	K(4),S72,14RM78,12RM78	14.59	11.57	7.22	70.74	1.84
Maui Agr.	21	K(2),21RM66	15.71	11.72	6.77	61.46	1.74
Ewa	5	K(2),20RM78	13.98	11.57	7.66	66.22	1.34
Pioneer	10	K,2RC60,S54,12RM72	15.09	11.42	7.09	56.29	1.88
Waialua	17	K(2),14RM78	14.92	12.64	7.38	51.3	1.46
Haw. Sug.	16	K,2RC72,S72,12RM78	15.11	11.65	7.20	41.34	1.17
Olaa	36	K,S72,12RM78	12.11	13.52	9.09	49.64	1.76
Honolulu	13	K(2),S54,11RM78	14.23	12.56	8.15	38.43	1.36
Onomea	34	2RC60,S54,12RM66	12.35	12.60	8.51	39.29	1.56
Kekaha	25	2RC54,9RM60	14.36	12.32	7.64	26.78	1.61
Hakalau	7	2RC54,12RM9-60,3-66	13.34	12.82	7.86	32.47	1.56
Hilo	33	K,2RC60,12RM66	13.10	13.65	8.13	34.00	1.35
McBryde	12	K,S54,9RM84	13.38	12.62	8.35	37.63	1.54
Wailuku	2	K,2RC72,12RM78	14.16	13.55	7.50	33.47	0.95
Haw. Agr.	30	3RC60,12RM66	12.59	13.49	8.61	45.42	1.80
Lihue	27	K,2RM72,12RM78	13.23	13.46	8.45	43.94	1.25
Waiakea	3	K(2),S42,11RM60	12.98	13.15	8.77	27.18	1.63
Honokaa	35	K(2),14RM2-60,12-66	11.54	12.78	9.80	36.28	1.44
Laupahoehoe	41	K(2),11RM60	13.18	13.02	8.00	23.72	1.42
Makee	14	K(2)),9RM72	12.74	12.43	9.23	40.51	2.25
Lihue, Han.	46	K,2RC72,9RM78	12.64	13.18	8.95	36.57	1.29
Kahuku	43	3RC60,S54,9RM72	11.96	13.29	9.53	20.69	0.86
Pepeekeo	19	2RC54,9RM60	12.97	12.89	8.22	22.47	1.35
Paauhau	24	2RC60,12RM66	12.31	13.67	8.61	29.68	1.18
Koloa	38	K,2RC60,12RM66	13.03	14.19	8.75	31.16	1.24
Honomu	37	2RC60,9RM60	12.41	12.07	7.93	22.11	1.22
Hawi	26	K(6),3RC48,12RM3-48,9-54,S42,9RM54	13.65	12.07	8.32	35.71	1.32
Hamakua	15	K(2),2RC60,9RM60	12.81	13.46	8.76	24.10	1.44
Hutchinson	31	2RC60,9RM60	12.79	13.50	8.59	26.37	1.68
Kaeleku	47	K(2),11RM2-54,9-60	10.86	14.07	10.69	22.99	1.56
Kaiwiki	32	K(2),11RM60	12.20	14.07	8.02	22.49	1.36
Kilauea	23	K,3RC36,9RM60	11.20	12.25	10.43	24.39	1.46
Kohala	40	K(2),S42,11RM60	13.03	12.07	8.25	26.41	1.59
Waianae	9	K,12RM66	14.35	13.53	7.98	24.50	1.88
Waimanalo	1	K,3RM,6-54,2-60	....	....	9.31	17.60	1.74
Niulii	39	K(2),9RM54	13.52	12.90	8.42	14.40	1.42
Halawa	29	K,2RC60,6RM60	12.53	13.21	9.88	13.84	1.59
Olowalu	18	K,3RC48,9RM48	13.85	13.36	8.65	15.25	1.43
Waimea	4	2RC48,12RM42	12.84	10.65	8.58	15.28	1.5
Kipahulu	44	K,3RM,3-42,2-54	14.35	15.43	9.84	11.50	2.12
True Average, 1919		....	13.74	12.49	7.94	....	....
" " 1918		....	12.97	12.50	8.51	....	....
" " 1917		....	13.76	12.62	8.03	....	....
" " 1916		....	13.24	12.74	8.16	....	....
" " 1915		....	13.77	12.51	7.98	....	....
" " 1914		....	13.78	12.74	8.13	....	....
" " 1913		....	14.05	12.85	8.14	....	....
" " 1912		....	14.03	12.71	7.99	....	....
" " 1911		....	13.90	12.86	8.16	....	....
" " 1910		....	14.47	12.30	7.99	....	....

Factory	BAGASSE Polarization	% Moisture	% Fiber	Pol. per 100 cane	Pol. per 100 pol. of cane	Pol. per 100 Fiber "Milling Loss"	Weight per 100 cane
H. C. & S. Co.	0.91	39.27	59.30	0.16	1.01	1.53	17.94
Oahu	1.78	42.84	54.54	0.38	2.59	3.26	21.20
Maui Agr.	0.71	43.37	55.52	0.15	0.95	1.28	21.11
Ewa	1.21	43.30	54.94	0.26	1.83	2.20	21.11
Pioneer	1.82	43.43	53.88	0.38	2.55	3.38	21.19
Waialua	1.68	42.67	54.99	0.38	2.59	3.06	22.99
Haw. Sug.	1.69	42.02	55.65	0.35	2.34	3.04	20.94
Olaa	1.30	44.15	53.95	0.32	2.68	2.41	24.88
Honolulu	1.73	41.43	55.90	0.39	2.72	3.09	22.40
Onomea	0.83	38.93	59.62	0.18	1.42	1.39	21.13
Kekaha	1.90	39.52	57.81	0.40	2.81	3.28	21.31
Hakalau	1.07	37.37	61.05	0.23	1.69	1.75	21.00
Hilo	1.17	36.61	61.84	0.26	1.97	1.88	22.10
McBryde	1.52	42.43	55.30	0.35	2.60	2.75	22.83
Wailuku	1.22	41.03	57.26	0.29	2.05	2.13	23.67
Haw. Agr.	1.62	39.68	58.15	0.37	2.99	2.79	23.19
Lihue	1.62	42.88	54.70	0.40	3.01	2.96	24.63
Waiakea	2.10	41.90	55.10	0.50	3.87	3.81	23.83
Honokaa	1.65	42.99	54.51	0.39	3.36	3.03	23.47
Laupahoehoe	1.60	41.05	56.78	0.37	2.78	2.82	22.93
Makee	3.21	41.38	54.26	0.73	5.77	5.90	22.91
Lihue, Han.	2.20	42.58	54.36	0.53	4.23	4.05	24.24
Kahuku	1.65	40.48	56.75	0.38	3.22	2.91	23.42
Pepeekeo	1.23	38.60	59.73	0.26	2.04	2.06	21.58
Paauhau	1.36	40.16	57.94	0.32	2.57	2.34	23.06
Koloa	1.53	40.64	56.90	0.38	2.93	2.69	24.94
Honomu	1.26	38.80	58.90	0.30	2.43	2.55	20.50
Hawi	2.82	42.48	53.71	0.67	4.84	5.25	23.76
Hamakua	2.89	42.08	54.10	0.71	5.55	5.29	24.88
Hutchinson	2.17	39.33	57.80	0.51	3.99	3.76	23.47
Kaeleku	2.32	41.05	55.04	0.53	4.16	3.95	23.29
Kaiwiki	2.41	41.77	54.90	0.56	4.59	4.19	23.38
Kilauea	1.54	40.62	56.89	0.33	2.95	2.71	21.45
Kohala	2.33	41.46	55.58	0.50	3.85	4.19	21.54
Waianae	1.55	41.15	56.61	0.37	2.58	2.74	23.89
Waimanalo	....	....	....	....	....	....	....
Niulii	4.42	46.32	47.85	1.20	....	9.18	27.27
Halawa	4.34	44.83	49.67	1.15	9.21	8.74	26.62
Olowalu	2.68	43.13	53.02	0.67	4.80	5.05	25.12
Waimea	0.94	37.64	61.01	0.17	1.30	1.54	17.76
Kipahulu	4.75	49.80	44.28	1.51	11.15	10.73	31.77
True Average, 1919	1.67	41.57	56.05	0.37	2.70	2.97	22.27
" " 1918	1.59	42.70	55.04	0.36	2.79	2.90	22.74
" " 1917	1.78	42.06	55.31	0.41	2.95	3.25	22.83
" " 1916	1.81	42.49	54.58	0.42	3.13	3.30	23.19
" " 1915	2.17	43.87	53.07	0.51	3.72	4.09	23.57
" " 1914	2.49	45.72	50.87	0.63	4.52	4.93	24.75
" " 1913	3.07	47.11	48.71	0.81	5.75	6.30	26.36
" " 1912	3.43	....	49.57	0.88	6.11	6.93	26.56
" " 1911	3.55	....	49.31	0.93	6.41	7.20	26.10
" " 1910	....	....	....	0.92	....	....	25.76

Factory No.	FIRST MILL JUICE Brix	Polarization	Purity	Pol. of cane x 100 / Polarization	MIXED JUICE Brix	Polarization	Purity	Weight per 100 cane	Pol. per 100 cane	Pol. per 100 pol. of cane "Extraction"	Extraction Ratio
6	21.33	19.15	89.78	83.8	13.98	12.12	86.70	131.03	15.89	98.99	0.09
20	20.66	18.16	87.90	80.3	13.82	11.71	84.74	121.39	14.21	97.41	0.22
21	21.08	18.94	89.85	82.9	14.21	12.33*	86.77	126.15	15.56	99.05	0.08
5	19.12	16.59	86.30	84.7	12.39	10.24	82.65	134.02	13.73	98.17	0.16
10	20.83	18.49	88.76	81.6	14.97	12.82	85.60	114.73	14.71	97.45	0.22
17	20.36	18.16	89.2	82.2	14.92	12.67	85.7	124.54	14.54	97.41	0.20
16	20.77	18.22	87.72	82.9	14.92	12.71	85.10	116.10	14.76	97.66	0.20
36	17.52	15.24	87.0	79.5	12.71	10.56	83.1	111.61	11.79	97.32	0.20
13	20.11	17.44	86.7	81.6	13.08	11.10	84.86	124.71	13.84	97.28	0.22
34	16.07	14.22	88.5	86.8	11.77	10.08	85.6	118.37	11.93	98.58	0.11
25	19.05	16.71	87.71	85.9	13.19	11.23	85.14	124.26	13.96	97.19	0.23
7	18.14	15.94	87.9	83.7	13.15	11.15	84.8	117.61	13.12	98.31	0.13
33	17.38	15.17	87.28	86.4	12.52	10.64	85.06	110.79	11.84	98.03	0.14
12	19.70	16.90	85.79	79.2	12.09	9.96	82.38	130.78	13.03	97.40	0.21
2	19.82	17.29	87.2	81.9	14.10	11.93	84.6	116.52	13.87	97.95	0.15
30	17.73	15.72	88.68	80.1	14.40	12.40	86.07	98.56	12.22	97.01	0.22
27	18.90	16.00	84.7	82.7	13.28	11.02	82.4	116.40	12.63	96.99	0.25
3	18.31	15.70	86.22	82.7	13.04	10.84	83.13	115.13	12.48	96.13	0.39
35	17.57	15.09	85.89	76.5	12.63	10.45	81.45	106.74	11.15	96.64	0.26
41	17.53	15.59	88.93	84.5	11.20	9.62	85.88	133.10	12.81	97.22	0.21
14	18.85	16.00	84.90	79.7	13.17	10.87	82.5	110.30	11.49	94.23	0.46
46	18.39	15.78	85.8	80.0	12.89	10.54	81.8	114.83	12.11	95.77	0.42
43	18.00	15.42	82.90	77.6	11.96	9.66	80.77	119.91	11.58	96.78	0.24
19	17.95	15.57	87.30	82.0	13.30	11.26	84.10	118.94	13.54	97.96	0.16
24	18.48	16.31	88.26	76.7	12.78	10.67	83.46	114.29	12.19	97.43	0.19
38	19.61	16.49	84.1	79.0	12.82	10.30	80.3	122.80	12.65	97.07	0.21
37	18.13	15.99	88.2	83.0	13.25	11.23	84.5	116.57	13.09	97.61	0.20
26	18.99	16.71	88.00	82.9	12.97	10.85	83.7	105.35	11.26	95.16	0.49
15	17.99	15.55	86.4	80.0	12.97	10.81	83.3	105.15	11.45	94.45	0.41
31	17.75	15.81	89.1	81.0	13.08	11.18	85.6	109.79	12.28	96.01	0.29
47	16.24	13.53	83.31	80.9	12.80	10.32	80.43	100.32	10.36	95.65	0.48
32	19.46	17.01	87.40	79.1	14.49	12.04	83.10	107.09	12.90	95.31	0.34
23	17.76	14.73	82.9	76.1	12.82	10.19	79.5	106.75	10.87	96.86	0.23
40	17.8	15.64	87.9	83.2	12.8	10.84	84.7	115.62	12.53	96.15	0.32
9	21.02	17.92	85.27	80.1	13.90	11.44	82.3	122.20	13.98	97.42	0.19
1	18.55	15.46	83.29	....	15.67	12.75	81.36	....	....	....	....
39	18.1	15.91	87.9	85.0	16.1	13.78	85.6	....	....	....	....
29	17.75	15.35	86.48	81.6	14.39	12.05	83.74	94.39	11.37	90.79	0.70
18	20.09	17.18	85.52	80.6	15.94	13.06	81.93	100.89	13.18	95.14	0.37
4	19.83	16.84	84.9	76.2	13.95	11.45	82.08	110.71	12.67	98.70	0.13
44	17.77	15.61	87.28	87.4	12.48	10.69	84.99	105.22	11.24	88.85	0.79
1919	19.17	16.74	87.34	82.0	13.39	11.29	84.29	118.29	13.37	97.30	0.22
1918	18.26	15.92	87.18	81.3	12.92	10.85	83.99	116.05	12.60	97.21	0.22
1917	19.14	16.85	88.02	81.6	13.48	11.45	84.94	116.53	13.24	97.05	0.25
1916	18.64	16.34	87.70	82.3	13.17	11.14	84.59	116.99	13.03	96.87	0.25
1915	18.87	16.65	88.24	82.7	14.03	11.89	84.75	111.44	13.26	96.30	0.32
1914	19.30	17.04	88.29	81.2	14.56	12.34	84.75	106.14	13.15	95.46	0.46
1913	19.28	17.17	89.02	81.8	....	12.40	....	103.07	13.24	94.25	0.45
1912	....	....	....	....	....	12.99	....	105.23	13.46	93.89	0.48
1911	....	....	....	....	....	12.75	....	103.07	13.21	93.54	0.50
1910	....	....	....	....	....	....	....	102.87	13.52	93.63	....

Factory No.	LAST MILL JUICE Polarization	Purity	MACERATION WATER Weight per 100 cane	Dilution % normal juice	Factory No.	Clarified juice purity	SYRUP Brix	Purity	Increase in Purity
6	0.63	63.60	49.10	50.84	6	87.97	58.88	87.98	1.28
20	1.74	68.23	42.0	41.60	20	86.47	65.41	86.5	1.76
21	0.75	64.66	47.3	46.87	21	87.12	66.76	88.09	1.32*
5	0.95	68.84	55.1	61.22	5	84.44	65.08	84.28	1.63
10	1.00	67.54	35.9	36.34	10	85.87	64.93	85.85	0.25
17	2.50	71.8	47.5	46.9	17	86.5	65.06	86.7	1.00
16	1.87	72.48	37.0	36.4	16	85.41	59.75	85.56	0.37
36	1.11	67.7	36.5	33.8	36	86.5	61.47	86.5	3.4
13	0.94	64.7	47.3	47.8	13	87.0	63.68	87.22	2.36
34	1.15	67.1	41.9	40.58	34	86.4	64.90	86.9	1.3
25	1.47	76.17	45.6	46.55	25	85.98	60.70	85.95	0.81
7	1.50	67.9	38.6	37.95	7	85.9	59.01	86.1	1.3
33	2.75	74.93	32.9	31.20	33	85.90	65.85	87.04	1.98
12	1.81	67.04	53.6	54.51	12	83.4	62.21	83.96	1.58
2	1.28	71.3	39.9	37.70	2	84.7	60.73	84.8	0.5
30	4.10	76.58	21.7	17.88	30	87.09	60.71	87.68	1.61
27	0.97	67.0	41.0	41.25	27	83.6	58.42	82.9	0.5
3	2.79	71.54	39.0	38.65	3	84.45	49.80	85.54	2.41
35	2.12	66.54	30.2	27.44	35	82.87	58.79	83.11	1.66
41	2.51	73.69	66.1	58.07	41	86.73	63.73	87.89	2.01
14	5.09	74.20	33.3	34.77	14	82.50	63.24	82.50	0.0
46	1.34	72.0	39.1	38.79	46	82.6	58.18	83.6	1.8 ‡
43	1.00	59.53	43.3	50.85	43	81.01	60.61	80.68	—0.09
19	2.14	72.99	34.4	32.71	19	85.74	64.60	86.05	1.95
24	1.47	66.25	37.9	36.30	24	85.08	61.15	85.15	1.69 ‡
38	0.88	62.2	47.7	48.36	38	80.9	60.68	81.4	1.1
37	1.73	68.2	37.1	36.42	37	86.5	58.36	86.7	2.2
26	2.36	74.90	29.1	27.70	26	86.12	59.85	86.09	0.89
15	2.46	74.40	28.1	38.6	15	85.6	62.09	84.5	1.4
31	1.74	68.5	33.3	33.0	31	86.2	58.15	86.2	0.6
47	3.47	70.10	25.6	24.61	47	81.95	55.30	81.82	1.39
32	2.87	72.48	30.2	28.92	32	85.60	61.39	85.65	2.55
23	1.73	61.8	28.2	26.28	23	80.6	61.2	80.7	1.2
40	2.19	77.3	37.2	37.5	40	86.4	67.8	85.6	0.9
9	1.04	69.33	46.1	45.74	9	82.72	63.33	83.36	1.59
1	....	....	....	18.20	1	....	....	....	...
39	5.85	80.4	....	12.84	39	87.41	63.39	87.5	1.9
29	7.37	79.09	21.0	20.29	29	85.32	57.36	85.93	2.19
18	4.35	69.66	26.0	23.53	18	82.71	64.62	82.59	0.66
4	1.56	68.05	28.5	41.0	4	....	58.73	85.57	3.49
44	5.17	80.28	36.9	32.02	44	86.06	62.91	85.83	0.84
1919	1.70	68.53	40.80	....	1919	....	62.42	85.70	1.41
1918	1.56	69.52	38.99	....	1918	....	61.66	85.78	1.79
1917	1.71	71.15	39.98	....	1917	....	62.28	86.36	1.48
1916	1.75	71.71	39.85	....	1916	....	62.73	86.18	1.59
1915	1.96	73.88	35.04	....	1915	....	61.64	86.59	1.84
1914	2.28	74.90	33.64	....	1914	....	60.93	87.31	1.61
1913	....	....	33.42	....	1913	....	....	....	...
1912	....	....	30.79	....	1912	....	....	....	...
1911	....	....	29.17	....	1911	....	....	....	...
1910	....	....	28.63	....	1910	....	....	....	...

Factory No.	PRESS CAKE Polarization	Weight per 100 cane	Pol. per 100 cane	Pol. per 100 pol. of cane	LIME USED (Weight For 100 Cane) In Juice	In Settlings	Total	COMMERCIAL SUGAR Polarization	% Moisture	Weight per 100 cane	Pol. per 100 cane	Pol. per 100 pol. of cane	Pol. per 100 pol. of juice	Total weight in thousand tons	Factory No.
6	1.77	3.16	0.02	0.15	...	...	0.09	96.13	1.20	15.40	14.81	92.25	93.20	50	6
20	1.07	2.73	0.03	0.20	0.05	0.03	0.07	96.30	1.00	13.85	13.34	91.42	93.86	44	20
21	1.53	2.86	0.04	0.27	...	...	0.07	96.50*	0.85	14.77	14.27	90.84	91.71	28	21
5	1.59	2.25	0.04	0.26	0.07	0.02	0.09	96.47	0.95	13.06	12.60	90.15	91.82	38	5
10	0.69	2.75	0.02	0.13	0.07	0.01	0.08	96.90	0.93	14.11	13.55	89.77	92.12	30	10
17	0.85	2.21	0.02	0.13	...	...	0.08	96.83	0.84	13.34	13.11	87.88	90.21	31	17
16	2.55	2.13	0.05	0.36	0.06	0.01	0.06	96.45	1.04	13.88	13.39	88.63	90.75	24	16
36	2.83	1.30	0.04	0.30	...	...	0.05	96.70	0.73	11.00	10.63	87.80	90.22	24	36
13	0.73	2.72	0.02	0.14	...	...	...	...	...	...	...	...	....	20 †	13
34	0.77	2.42	0.01	0.07	...	...	0.07	96.30	0.77	11.75	11.33	91.73	93.05	20	34
25	2.02	2.65	0.06	0.40	0.09	0.02	0.11	96.57	0.81	13.09	12.64	88.03	90.58	15	25
7	0.96	2.95	0.03	0.21	0.05	...	0.05	95.74	1.08	12.73	12.18	91.28	92.84	19	7
33	1.30	2.19	0.03	0.22	0.05	...	0.05	95.58	1.03	12.29	11.87	90.61	92.43	14	33
12	1.03	1.42	0.01	0.11	0.04	0.02	0.06	96.36	1.13	11.98	11.54	86.27	88.57	18	12
2	1.36	2.77	0.04	0.27	...	...	0.18	96.24	0.95	13.33	12.83	90.62	92.41	17	2
30	0.49	1.82	0.01	0.04	0.09	...	0.09	96.32	0.79	11.62	11.19	88.87	91.60	17	30
27	2.37	1.84	0.04	0.33	0.08	0.01	0.09	96.19	1.00	11.84	11.39	86.10	88.78	16	27
3	1.28	2.04	0.03	0.20	...	...	0.05	96.21	...	11.40	10.97	84.49	87.89	12	3
35	1.21	1.82	0.02	0.19	0.04	0.01	0.05	96.27	1.01	10.21	9.83	85.16	88.12	14	35
41	0.90	2.17	0.02	0.15	0.05	...	0.05	96.24	1.35	12.50	12.03	91.27	93.88	8	41
14	3.12	1.52	0.05	0.37	0.06	0.02	0.08	96.68	...	10.83	10.47	82.22	87.25	15	14
46	2.10	1.88	0.04	0.31	0.10	0.03	0.13	96.27	0.95	11.17	10.76	85.09	88.85	6	46
43	1.25	1.66	0.02	0.17	0.07	...	0.07	96.30	0.97	10.49	10.11	84.46	87.27	9	43
19	0.64	2.47	0.02	0.12	0.06	...	0.06	96.26	0.82	12.16	11.71	90.28	92.16	9	19
24	1.67	2.64	0.04	0.35	0.05	0.01	0.06	96.36	0.92	11.61	11.19	89.46	91.82	7	24
38	1.39	2.33	0.03	0.25	0.05	0.01	0.06	96.17	0.94	11.43	10.99	84.31	86.86	9	38
37	1.56	2.41	0.04	0.28	...	...	0.06	96.41	0.78	12.61	12.16	90.68	92.90	8	37
26	1.92	3.06	0.06	0.42	0.07	0.04	0.11	95.96	...	12.02	11.54	83.30	87.54	8	26
15	0.78	1.56	0.01	0.09	0.06	...	0.06	96.47	0.99	11.41	11.01	85.94	90.98	11	15
31	0.63	1.84	0.01	0.09	0.06	...	0.06	96.38	0.99	11.64	11.22	87.74	91.38	6	31
47	3.22	1.82	0.06	0.54	0.05	0.02	0.07	96.84	1.00	9.36	9.06	82.77	87.44	5	47
32	0.88	3.69	0.03	0.24	0.07	...	0.07	96.03	1.0	12.47	11.98	88.95	92.83	6	32
23	1.11	2.54	0.03	0.25	0.07	...	0.07	96.67	0.93	9.58	9.26	82.69	85.20	5	23
40	1.02	2.60	0.03	0.20	0.11	...	0.11	96.52	0.96	12.11	11.69	89.71	93.30	7	40
9	2.73	2.47	0.07	0.47	0.05	0.01	0.06	96.65	0.89	12.53	12.11	84.37	86.61	6	9
1	3.49	2.40	0.08	...	0.08	...	0.08	94.93	...	10.74	10.16	....	....	5	1
39	2.62	2.33	0.06	...	0.08	0.01	0.09	96.29	...	11.87	11.43	....	....	3	39
29	1.04	0.84	0.01	0.07	0.09	...	0.09	95.49	...	10.12	9.66	77.15	84.98	3	29
18	2.18	1.59	0.04	0.25	...	...	0.02	95.80	...	11.56	11.07	79.94	84.02	2	18
4	1.1	2.04	0.02	0.18	0.05	0.01	0.06	96.4	...	11.66	11.24	87.50	88.65	2	4
44	6.33	2.17	0.14	1.02	0.06	0.03	0.09	97.07	...	10.49	10.18	75.14	84.57	2	44
1919	1.34	2.32	0.03	0.22	...	...	0.076	96.34	0.96	12.59	12.13	88.57	90.96	..	1919
1918	1.48	2.36	0.03	0.26	...	...	0.072	96.53	0.94	11.75	11.34	87.91	90.37	..	1918
1917	1.52	2.28	0.03	0.25	...	...	0.063	96.87	0.87	12.45	12.06	87.93	90.58	..	1917
1916	1.82	2.20	0.04	0.30	...	...	0.06	96.31	1.06	12.25	11.80	87.98	90.84	..	1916
1915	1.81	1.89	0.03	0.25	...	...	0.07	96.40	0.98	12.52	12.07	87.65	91.03	..	1915
1914	1.76	1.78	0.03	0.23	...	...	...	96.66	0.93	12.30	11.89	86.56	90.95	..	1914
1913	1.99	1.72	0.03	0.24	...	...	...	97.03	...	12.29	11.93	84.95	90.12	..	1913
1912	...	...	...	...	...	...	...	97.21	...	12.51	12.16	85.66	91.30	..	1912
1911	...	...	...	...	...	...	...	97.55	...	12.25	11.95	85.50	91.41	..	1911
1910	...	...	...	...	...	...	...	97.42	...	12.51	12.18	84.46	90.16	..	1910

Factory No.	FINAL MOLASSES Weight per 100 cane	Sucrose per 100 cane	Sucrose per 100 pol. of cane	Sucrose per 100 pol. of juice	Gravity solids	Gravity purity	True purity	OTHER KNOWN LOSSES Pol. per 100 cane	Pol. per 100 pol. of cane	UNDETERMINED LOSSES Pol. per 100 cane	Pol. per 100 pol. of cane	Factory No.	Factory
6	2.73	0.94	5.84	5.90	85.61	40.17	43.27	...	...	0.12	0.74	6	H. C. & S. Co.
20	2.35	0.78	5.35	5.49	91.7	36.3	....	...	...	0.06	0.43	20	Oahu
21	3.41	1.11	7.08	7.15	84.43	38.64	....	...	...	0.13	0.86	21	Maui Agr.
5	3.18	1.03	7.34	7.48	91.89	35.13	....	...	...	0.06	0.43	5	Ewa
10	2.81	0.93	6.19	6.35	88.83	37.48	....	0.02	0.16	0.19	1.21	10	Pioneer
17	3.22	1.10	7.34	7.54	87.58	38.9	42.3	...	...	0.31	2.07	17	Waialua
16	3.43	1.17	7.74	7.93	86.39	39.53	....	...	...	0.14	0.93	16	Haw. Sug.
36	3.28	1.08	8.93	9.18	84.80	38.9	....	...		0.04	0.29	36	Olaa
13	3.54	1.24	8.75	8.99	87.64	40.14	....	...		...	...	13	Honolulu
34	2.37	0.73	5.89	5.98	87.40	35.17	....	...	...	0.11	0.89	34	Onomea
25	3.28	1.16	8.06	8.29	90.03	39.25	43.87	...	...	0.10	0.70	25	Kekaha
7	2.37	0.73	5.44	5.53	85.34	35.84	37.70	...	...	0.18	1.39	7	Hakalau
33	2.50	0.75	5.72	5.84	85.85	34.94	....	...	...	0.19	1.48	33	Hilo
12	4.15	1.41	10.55	10.83	86.74	39.19	....	...	...	0.06	0.47	12	McBryde
2	3.16	1.00	7.10	7.25	86.87	36.65	....	...	...	0.01	0.07	2	Wailuku
30	2.76	0.90	7.09	7.31	82.37	39.37	41.60	...	...	0.12	0.98	30	Haw. Agr.
27	...	...	...	...	84.20	37.5	....	...	...	1.40	10.56	27	Lihue
3	...	...	...	...	83.99	42.11	....	...		1.48	11.41	3	Waiakea
35	3.98	1.20	10.38	10.74	81.25	37.00	....	...		0.10	0.91	35	Honokaa
41	2.18	0.73	5.57	5.73	86.06	39.12	....	...	...	0.03	0.25	41	Laupahoehoe
14	3.73	1.34	10.56	11.20	92.11	39.10	....	...	...	0.14	1.09	14	Makee
46	...	...	...	...	90.47	36.2	....	...	...	1.31	10.37	46	Lihue, Han.
43	3.86	1.31	10.95	11.31	94.50	35.88	....	...	...	0.14	1.19	43	Kahuku
19	2.46	0.70	5.41	5.52	83.13	34.32	38.21	...	...	0.28	2.15	19	Pepeekeo
24	3.11	0.95	7.61	7.81	83.27	36.76	....	...		0.00	[illegible]	24	Paauhau
38	4.03	1.39	10.69	11.01	89.4	38.7	....	...	...	0.24	1.82	38	Koloa
37	2.72	0.77	5.72	5.86	81.24	34.7	....	...	...	0.12	0.93	37	Honomu
26	...	...	...	...	....	....	....	...		1.58	11.43	26	Hawi
15	1.66	0.58	4.54	4.81	87.17	40.3	....	...		0.50	3.88	15	Hamakua
31	2.41	0.80	6.21	6.47	81.14	40.71	....	...		0.25	1.97	31	Hutchinson
47	...	...	...	...	88.1	43.5	49.2	...	...	1.24	11.55	47	Kaeleku
32	...	...	...	...	87.80	38.73	....	...	...	0.89	6.62	32	Kaiwiki
23	3.70	1.37	12.24	12.61	91.18	40.64	....	...		0.21	1.87	23	Kilauea
40	2.31	0.80	6.13	6.38	90.76	38.06	42.90	...		0.02	0.11	40	Kohala
9	...	...	...	...	85.31	40.14	44.28	...	...	1.81	12.58	9	Waianae
1	...	...	...	...	....	....	....	...	...	...	...	1	Waimanalo
39	...	...	...	...	87.4	43.6	48.9	...	...	...	...	39	Niulii
29	...	...	...	...	....	....	....	...		1.70	13.56	29	Halawa
18	2.02	0.74	5.33	5.60	86.77	42.22	....	...		1.33	9.62	18	Olowalu
4	...	...	...	...	....	....	....	...		1.42	11.02	4	Waimea
44	...	...	...	...	....	....	....	...		1.72	12.49	44	Kipahulu
1919	3.02	1.00	7.24	7.42	87.34	37.95	....	...	...	...	...	..	1919
1918	3.04	1.04	7.96	8.17	87.32	39.07	....	...	...	...	...	..	1918
1917	3.07	1.07	7.68	7.89	86.68	40.03	....	...	...	...	...	..	1917
1916	2.90	0.98	7.41	7.64	87.63	39.25	....	...	...	...	...	..	1916
1915	2.81	0.97	6.98	7.22	87.36	39.69	....	...	...	...	...	..	1915
1914	2.80	0.99	7.12	7.43	87.87	40.40	....	...	...	...	...	..	1914
1913	...	...	...	...	....	....	....	...	...	...	...	..	1913
1912	...	...	...	...	....	....	....	...	...	...	...	..	1912
1911	...	...	...	...	....	....	....	...	...	...	...	..	1911
1910	...	...	...	...	....	....	....	...	...	...	...	..	1910

* Sucrose.
† Refined Sugar.
‡ Probably incorrect on account of remelted low grade sugar in syrup.

CANE MILL DATA, SEASON OF 1919

Milling Plant and Revolving Knives

Factory	Factory No.	Milling Plant (Sizes in Inches)	Revolving Knives, First Set: Number	Distance Apart Inches	Distance from Conveyor Inches	Revolutions per Minute	Revolving Knives, Second Set: Number	Distance Apart Inches	Distance from Conveyor Inches	Revolutions per Minute
H. C. & S. Co.	6	K(2),2RC34x78,S72,12RM34x78	28	9	24	1200	44	6	16	1200
"	6	K(2),2RC34x78,S72,12RM34x78	28	9	24	1200	44	6	16	1200
Oahu	20	K(2),S72,14RM2-33x78,12-34x78	26	4	24	490	54	2	2 1/2	690
"	20	K(2),12RM34x78	11	7	30	290	52	2	3	690
Maui Agr.	21	K(2),21RM34x66	72	7/8	10	450	72	7/8	7/8	520
Ewa	5	K(2),20RM2-32x78,18-34x78	12	6	18	350	80	7/8	1	600
Pioneer	10	K,2RC24x60,S54,12RM34x72	13	4	6	535	..	....	....	...
Waialua	17	K(2),14RM2-33x78,12-34x78	36	4	12	650	50	5 1/2	1	650
Haw. Sug.	16	K,2RC26x72,S72,12RM34x78	38	1 1/2	8	400	..	....	....	...
Olaa	36	K,S72,12RM34x78	46	....	5	450	..	....	....	...
Honolulu	13	K(2),S54,11RM34x78	24	6	18	450	24	6	4	500
Onomea	34	2RC24x60,S54,12RM32x66	..	....	....	...	..	....	....	...
Kekaha	25	2RC24x54,9RM32x60	..	....	....	...	..	....	....	...
Hakalau	7	2RC24x54,12RM9-32x60,3-32x66	..	....	....	...	..	....	....	...
Hilo	33	K,2RC24x60,12RM32x66	10	6	8	275	..	....	....	...
McBryde	12	K,S54,9RM34x84	24	6	4	350	..	....	....	...
Wailuku	2	K,2RC24x72,12RM34x78	10	6	6	400	..	....	....	...
Haw. Agr.	30	3RC32x60,12RM32x66	..	....	....	...	..	....	....	...
Lihue	27	K,2RC26x72,12RM34x78	10	6	12	240	..	....	....	...
Waiakea	3	K(2),S42,11RM2-30x60,9-32x60	13	5	1	300	40	2	1/2	418
Honokaa	35	K(2),14RM2-30x60,12-32x66	68	1 3/4	16	350	108	17/32	1 1/4	450
Laupahoehoe	41	K(2),11RM2-30x60,9-32x60	16	3 3/4	3/4	450	40	2 1/4	3/4	500
Makee	14	K(2),9RM34x72	12	6	12	320	80	7/8	5	500
Lihue, Han.	46	K,2RC26x72,9RM34x78	11	6 1/4	10	285	..	....	....	...
Kahuku	43	3RC30x60,S54,9RM34x72	..	....	....	...	..	....	....	...
Pepeekeo	19	2RC24x54,9RM6-32x60,3-30x60	..	....	....	...	..	....	....	...
Paauhau	24	2RC24x60,12RM32x66	..	....	....	...	..	....	....	...
Koloa	38	K,2RC24x60,12RM32x66	12	5	9	300	..	....	....	...
Honomu	37	2RC30x60,9RM32x60	..	....	....	...	..	....	....	...
Hawi	26	K,3RC26x48,12RM3-26x48,9-30x54	14	3 1/4	1	420	..	....	....	...
"	26	K(2),S42,9RM30x54	8	7	6	380	11	4 3/4	1 1/4	400
Hamakua	15	K,2RC30x60,9RM32x60	60	2	1 1/2	500	..	....	....	...
Hutchinson	31	2RC30x60,9RM32x60	..	....	....	...	..	....	....	...
Kaeleku	47	K(2),11RM2-24x54,9-32x60	9	6	8	250	36	1 1/2	2	400
Kaiwiki	32	K(2),11RM2-26x60,9-32x60	16	3	2 1/2	375	40	3 1/2	2	400
Kilauea	23	K,S,3RC32x60,9RM32x60	10	5 1/2	1 1/2	250	..	....	....	...
Kohala	40	K(2),S42,11RM2-30x60,9-32x60	12	4	18	275	40	1 1/2	3	475
Waianae	9	K,12RM9-30x60,3-32x60	12	4 1/2	5 1/2	450	..	....	....	...
Waimanalo	1	K,8RM6-26x54,2-30x60	8	6	8	350	..	....	....	...
Niulii	39	K(2),9RM3-26x54,3-30x54,3-28x54	..	....	....	...	..	....	....	...
Halawa	29	K,2RC30x60,6RM26x50	20	4	3	1150	..	....	....	...
Olowalu	18	K,3RC28x48,9RM27x48	16	3	4	400	..	....	....	...
Waimea	4	2RC24x48,12RM26x42	..	....	....	...	..	....	....	...
Kipahulu	44	K,5RM3-24x42,2-26x54	20	2 1/2	1	500	..	....	....	...

Mill Openings—Inches

Factory	Factory No.	Crusher	1st Mill Front	1st Mill Back	2nd Mill Front	2nd Mill Back	3rd Mill Front	3rd Mill Back	4th Mill Front	4th Mill Back	5th Mill Front	5th Mill Back
H. C. & S. Co.	6	1/16	3/8	1/16	1/4	0	1/4	0	1/4	0	....	....
"	6	1/16	3/8	1/16	1/4	0	1/4	0	1/4	0	....	....
Oahu	20	....	1/2		5/8	0	5/8	1/16	5/8	0	5/8	0
"	20	....	5/8	1/8	5/8	1/16	5/8	0	5/8	0	....	....
Maui Agr.	21	....	7/16	1/16	13/16	0	9/16	0	1/4	0	5/8	3/16*
Ewa	5	....	3/4		1 1/4	1/4	1	0	7/8	0	1	0 †
Pioneer	10	....	5/8	1/32	9/16	0	1/2	0	3/8	0	....	....
Waialua	17	....	1/2		1/16	0	1/8	0	1/8	0	1/8	0
Haw. Sug.	16	1/4	7/16	3/32	5/16	1/16	1/4	0	3/16	0	....	....
Olaa	36	....	1	1/4	5/8	1/8	3/8	0	5/16	0	....	....
Honolulu	13	....	3/16		5/8	0	3/8	0	1/4	0	....	....
Onomea	34	1/2	3/4	1/8	1/2	1/16	1/2	0	3/8	0	....	....
Kekaha	25	3/8	1/2	0	3/8	0	1/4	0	....	....	....	....
Hakalau	7	1/8	5/8	0	1/8	0	3/16	0	1/4	0	....	....
Hilo	33	1/2	1/2	0	1/4	0	1/4	0	1/4	0	....	....
McBryde	12	....	7/16	0	3/8	0	1/4	0	....	....	....	....
Wailuku	2	0	1/2	0	5/16	0	1/4	0	3/16	0	....	....
Haw. Agr.	30	5/8x1/8	7/8	0	5/8	0	1/2	0	3/8	0	....	....
Lihue	27	1/16	7/8	1/8	5/8	3/32	1/2	0	5/16	0	....	....
Waiakea	3	....	....	....	....	....	....	....	....	....	....	....
Honokaa	35	....	1/4		3/4	1/16	1/2	1/32	3/8	0	5/16	0
Laupahoehoe	41	....	1/4		3/8	1/32	1/4	0	1/8	0	....	....
Makee	14	....	7/8	1/4	5/16	0	1/4	0	....	....	....	....
Lihue, Han.	46	0	1/2	1/8	5/16	1/32	1/8	0	....	....	....	....
Kahuku	43	4 5/8x3/8	1/2	3/16	1/4	1/16	1/8	0	....	....	....	....
Pepeekeo	19	0	1/2	0	3/32	0	3/32	0	....	....	....	....
Paauhau	24	0	5/16	0	3/16	0	3/16	0	1/8	0	....	....
Koloa	38	7/16	5/8	1/16	1/2	1/64	7/16	0	1/4	0	....	....
Honomu	37	3/8	5/16	0	1/4	0	3/16	0	....	....	....	....
Hawi	26	3/4x3/8	5/8	3/16	3/8	3/16	3/16	0	3/16	0	....	....
"	26	....	5/8	3/16	3/8	0	3/16	0	....	....	....	....
Hamakua	15	0	9/16	1/8	1/8	0	1/8	0	....	....	....	....
Hutchinson	31	1/2	3/8	0	3/16	0	3/32	0	....	....	....	....
Kaeleku	47	....	1/2		3/4	1/16	1/4	0	1/8	0	....	....
Kaiwiki	32	....	0		9/16	0	5/16	0	3/16	0	....	....
Kilauea	23	1/4x1/8	3/8	0	3/16	0	1/8	0	....	....	....	....
Kohala	40	....	3/8		1/4	0	3/16	0	1/16	0	....	....
Waianae	9	....	7/8	1/16	3/8	0	1/4	0	1/4	0	....	....
Waimanalo	1	....	3/4	3/16	5/16	0	0		....	....	....	....
Niulii	39	....	....	....	....	....	....	....	....	....	....	....
Halawa	29	1/2	3/8	1/8	1/8	0	....	....	....	....	....	....
Olowalu	18	3/8x1/8	15/32	1/16	5/16	0	1/4	0	....	....	....	....
Waimea	4	....	3/8	0	7/16	0	3/8	0	1/4	0	....	....
Kipahulu	44	....	3/4	3/16	1/16		....	....	....	....	....	....

Returner Bar—Distance from Top Roller—Inches

Factory	Factory No.	Crusher Toe	Crusher Center	Crusher Heel	1st Mill Toe	1st Mill Center	1st Mill Heel	2nd Mill Toe	2nd Mill Center	2nd Mill Heel	3rd Mill Toe	3rd Mill Center	3rd Mill Heel	4th Mill Toe	4th Mill Center	4th Mill Heel	5th Mill Toe	5th Mill Center	5th Mill Heel
H. C. & S. Co.	6	....	....	....	1 1/2	1 3/4	2	1 3/8	1 5/8	1 7/8	1 3/8	1 5/8	1 7/8	1 3/8	1 5/8	1 7/8	....	....	....
"	6	....	....	....	1 1/2	1 3/4	2	1 3/8	1 5/8	1 7/8	1 3/8	1 5/8	1 7/8	1 3/8	1 5/8	1 7/8	....	....	....
Oahu	20	....	....	....	....	....	....	....	1 1/4	....	....	1 1/2	....	....	1 1/2	....	....	1 1/2	....
"	20	....	....	....	....	1 3/4	....	....	1 1/2	....	....	1 1/2	....	....	1 1/2	....	....	....	....
Maui Agr.	21	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Ewa	5	....	....	....	....	....	....	1 3/4	2	2 1/4	1 3/4	2	2 1/4	1 3/4	2	2 1/4	1 3/4	2	2 1/4
Pioneer	10	....	....	....	1 1/2	1 5/8	1 7/8	1 1/4	1 3/8	1 3/4	1 1/4	1 3/8	1 3/4	1 1/4	1 3/8	1 1/2	....	....	....
Waialua	17	....	....	....	....	....	....	3/4	7/8	1 1/2	3/4	1 3/16	1 5/8	3/4	7/8	1 1/4	5/8	11/16	1 7/16
Haw. Sug.	16	....	....	....	1 1/4	1 1/2	2	1 1/4	1 1/2	2	1 1/4	1 1/2	2	1 1/4	1 1/2	2	....	....	....
Olaa	36	....	....	....	1 1/4	1 1/2	1 3/8	1	1 1/4	1 1/2	3/4	1	1 1/4	3/4	1	1 1/4	....	....	....
Honolulu	13	....	....	....	....	....	....	2 3/8	2 3/8	2 5/8	1 13/16	1 13/16	1 7/8	1 13/16	1 13/16	1 13/16	....	....	....
Onomea	34	....	....	....	1	1 1/2	1 3/4	1	1 1/2	1 3/4	1	1 1/4	1 1/2	1	1 1/4	1 1/2	....	....	....
Kekaha	25	....	....	....	1	1 1/2	2 1/4	3/4	1 1/4	2	3/4	1 1/4	2	....	....	....	....	....	....
Hakalau	7	....	....	....	13/16	1 1/16	2	3/8	3/4	1 7/8	3/8	15/16	2	5/16	3/4	1 7/8	....	....	....
Hilo	33	....	....	....	1 1/8	1 1/2	1 3/4	1 1/16	1 3/8	1 1/2	1 1/16	1 5/16	1 1/2	3/4	1	1 1/4	....	....	....
McBryde	12	....	....	....	1 1/2	1 13/16	2 5/16	1 3/8	1 1/2	1 7/8	1 1/8	1 5/16	1 3/4	....	....	....	....	....	....
Wailuku	2	....	....	....	1 3/4	2	2 1/8	1 3/4	2	2 1/2	1 3/4	2 1/16	2 1/16	1 1/2	1 3/4	2	....	....	....
Haw. Agr.	30	1 3/8	1 1/2	1 5/8	1 1/4	1 1/2	2	1 1/2	1 1/2	1 3/4	1 3/8	1 3/8	1 5/8	3/4	1	1 1/4	....	....	....
Lihue	27	....	....	....	1 1/4	1 1/2	1 7/8	1 1/8	1 3/8	1 3/4	3/4	1 3/16	1 1/2	5/8	1 1/8	1 5/8	....	....	....
Waiakea	3	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Honokaa	35	....	....	....	....	....	....	7/8	1 1/2	1 3/4	3/4	1 1/4	1 1/2	3/4	1 1/4	1 1/2	3/4	1 1/4	1 1/2
Laupahoehoe	41	....	....	....	....	....	....	....	1 1/2	....	....	1 1/8	....	....	3/4	....	....	....	....
Makee	14	....	....	....	1	1 1/4	1 1/5	1	1 1/4	1 1/5	1	1 1/4	1 1/5	....	....	....	....	....	....
Lihue, Han.	46	....	....	....	1 1/4	1 1/2	2	1	1 1/4	1 3/4	3/4	1	1 1/4	....	....	....	....	....	....
Kahuku	43	....	....	....	1 1/8	1 1/2	2	3/4	1 1/8	2	1/2	3/4	1	....	....	....	....	....	....
Pepeekeo	19	....	....	....	1	1 1/8	1 1/4	3/4	1 1/16	1 7/8	15/16	1 1/8	2 1/8	....	....	....	....	....	....
Paauhau	24	....	....	....	1 13/16	1 15/16	2 5/16	1	1 3/16	2	7/8	1 1/4	2	1 1/4	1 1/4	2 1/8	....	....	....
Koloa	38	....	....	....	1	1 1/2	2	1	1 1/4	1 1/2	3/4	1	1 1/4	3/4	1	1 1/4	....	....	....
Honomu	37	....	....	....	3/4	1	1 1/16	5/8	7/8	1	3/8	3/4	1	....	....	....	....	....	....
Hawi	26	1 1/4	1 1/2	1 3/4	1 1/8	1 1/4	1 1/2	1 1/8	1 1/4	1 1/2	1	1 1/8	1 3/8	7/8	1	1 1/4	....	....	....
"	26	....	....	....	1 1/4	1 3/8	1 1/2	1	1 1/8	1 3/8	7/8	1	1 1/4	....	....	....	....	....	....
Hamakua	15	....	....	....	....	1 5/8	....	....	1 1/2	....	....	1 1/8	....	....	....	....	....	....	....
Hutchinson	31	....	....	....	1 1/8	1 7/16	1 3/4	7/8	1 1/4	1 5/8	3/4	1	1 3/8	....	....	....	....	....	....
Kaeleku	47	....	....	....	....	....	....	1	1 1/2	2	1	1 1/8	1 5/8	1/2	3/4	1 1/4	....	....	....
Kaiwiki	32	....	....	....	....	....	....	1	1 1/2	2	1 1/8	1 1/2	2	1	1 1/8	1 3/4	....	....	....
Kilauea	23	1 7/16	1 1/2	1 5/8	1 7/16	....	1 7/16	1 3/16	1 1/4	1 3/8	1 3/16	1 1/4	1 3/8	....	....	....	....	....	....
Kohala	40	....	....	....	....	....	....	1 1/8	1 3/8	1 7/8	3/4	1 7/16	2	3/4	1 1/4	1 5/8	....	....	....
Waianae	9	....	....	....	1	1 1/4	1 1/2	5/8	3/4	1 1/2	3/8	7/8	7/8	1/2	5/8	7/8	....	....	....
Waimanalo	1	....	....	....	2	2 1/8	2 1/4	2	2 1/8	2 1/4	....	....	....	....	....	....	....	....	....
Niulii	39	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Halawa	29	....	....	....	11/16	1	1 3/4	1/2	3/4	1 1/4	....	....	....	....	....	....	....	....	....
Olowalu	18	3/8	1/2	7/8	27/32	21/32	3/4	1 1/16	1 5/16	1 11/16	1 1/16	1 5/16	1 5/8	....	....	....	....	....	....
Waimea	4	....	....	....	1 1/4	1 1/4	1 1/4	1 3/8	1 1/2	1 5/8	27/32	31/32	1 9/32	11/16	15/16	1 5/16	....	....	....
Kipahulu	44	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....

Returner Bar—Width—Inches, and Distance from Back Roller—Inches

Factory	Factory No.	Width 1st Mill	Width 2nd Mill	Width 3rd Mill	Width 4th Mill	Width 5th Mill	Width 6th Mill	Width 7th Mill	Back Roller 1st Mill	Back Roller 2nd Mill	Back Roller 3rd Mill	Back Roller 4th Mill	Back Roller 5th Mill	Back Roller 6th Mill	Back Roller 7th Mill
H. C. & S. Co.	6	13	12 1/2	11 1/4	12	....	....	....	1/2	1/2	1/2	1/2	....	....	....
"	6	13	12 1/2	11 1/4	12	....	....	....	1/2	1/2	1/2	1/2	....	....	....
Oahu	20	....	15	15	15	15	....	....	....	1/2	1/2	1/2	1/2	....	....
"	20	15	15	15	15	....	....	....	1/2	1/2	1/2	1/2	....	....	....
Maui Agr.	21	....	....	....	....	....	....	....	....	....	....	....	....	....	1/2
Ewa	5	....	....	....	....	....	....	....	....	1	1	3/4	1/2	1/2	3/8
Pioneer	10	12	13	13	13	....	....	....	3/8	1/2	1/2	1/2	....	....	....
Waialua	17	....	13 3/4	13 1/4	14	13 1/2	....	....	....	5/16	1/4	1/4	3/16	....	....
Haw. Sug.	16	13 1/2	13	13 1/4	13	....	....	....	3/8	3/8	3/8	3/8	....	....	....
Olaa	36	13	13	13	12	....	....	....	1	1	3/4	1/2	....	....	....
Honolulu	13	....	13	13	12 3/8	....	....	....	....	7/8	5/16	3/4	....	....	....
Onomea	34	12 1/2	12 1/2	11	12 1/2	....	....	....	1/2	1/2	1/2	1/2	....	....	....
Kekaha	25	11 1/2	12 1/2	11 1/2	....	....	....	....	1/2	3/8	3/8	....	....	....	....
Hakalau	7	12 1/4	11 1/4	12 1/16	12 1/4	....	....	....	1/2	1/2	1/4	1/4	....	....	....
Hilo	33	12 1/8	12 1/2	12	11 1/4	....	....	....	3/4	3/4	1/2	1/2	....	....	....
McBryde	12	....	....	....	....	....	....	....	1 3/4	1 5/8	1 7/16	....	....	....	....
Wailuku	2	11	11	13	14	....	....	....	3/4	1 1/4	1 5/8	7/8	....	....	....
Haw. Agr.	30	12 1/8	10 3/4	10 7/8	12	....	....	....	1/4	1 1/2	1 1/4	1/8	....	....	....
Lihue	27	13 1/2	13 3/8	13 1/2	13 3/4	....	....	....	3/4	3/4	9/16	1/2	....	....	....
Waiakea	3	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Honokaa	35	....	11	11	11	11	....	....	....	3/4	3/4	3/4	3/4	....	....
Laupahoehoe	41	....	11	10 1/2	10 1/4	....	....	....	....	3/8	1/2	3/8	....	....	....
Makee	14	13	13 1/2	13	....	....	....	....	1/2	3/4	1/4	....	....	....	....
Lihue, Han.	46	11	10 3/4	12 1/8	....	....	....	....	5/8	9/16	1/2	....	....	....	....
Kahuku	43	14	14 3/4	12 1/2	....	....	....	....	1/2	1/4	3/8	....	....	....	....
Pepeekeo	19	14 1/2	13 1/2	12 1/8	....	....	....	....	1/2	1/2	1/2	....	....	....	....
Paauhau	24	10 1/2	12 3/4	12 3/4	11 1/2	....	....	....	1/2	1/8	1/4	1/2	....	....	....
Koloa	38	12	12	12	12	....	....	....	1/4	1/4	1/4	1/4	....	....	....
Honomu	37	11 7/8	11 5/8	12 1/2	....	....	....	....	3/4	5/8	5/8	....	....	....	....
Hawi	26	10 1/2	12	12	12	....	....	....	3/8	3/8	3/8	3/8	....	....	....
"	26	12	11 1/2	11 1/2	....	....	....	....	1/2	3/8	3/8	....	....	....	....
Hamakua	15	....	....	....	....	....	....	....	1/2	1/2	3/8	....	....	....	....
Hutchinson	31	11 1/2	11 3/4	12 1/2	....	....	....	....	1/2	3/4	3/4	....	....	....	....
Kaeleku	47	....	14	12 1/2	14	....	....	....	....	3/4	3/4	1/2	....	....	....
Kaiwiki	32	....	11	11	11	....	....	....	....	1/2	3/8	1/4	....	....	....
Kilauea	23	....	....	....	....	....	....	....	3/8	3/8	1/4	....	....	....	....
Kohala	40	....	12	12	10	....	....	....	....	1/2	1/4	1/4	....	....	....
Waianae	9	12	12	12	12	....	....	....	1/2	1/2	1/2	1/2	....	....	....
Waimanalo	1	10 1/2	10	....	....	....	....	....	3/4	3/8	....	....	....	....	....
Niulii	39	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Halawa	29	11	10	....	....	....	....	....	1/2	1/4	....	....	....	....	....
Olowalu	18	11 1/16	11 1/16	11 1/16	....	....	....	....	1	0	1/16	....	....	....	....
Waimea	4	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Kipahulu	44	....	....	....	....	....	....	....	....	....	....	....	....	....	....

Speed of Rollers—Feet per Minute; Pressure on Rollers—Tons; Tons Cane per Hour; Tonnage Ratio

Factory	Factory No.	Speed Crusher	Speed 1st Mill	Speed 2nd Mill	Speed 3rd Mill	Speed 4th Mill	Speed 5th Mill	Speed 6th Mill	Speed 7th Mill	Pressure Crusher	Pressure 1st Mill	Pressure 2nd Mill	Pressure 3rd Mill	Pressure 4th Mill	Pressure 5th Mill	Pressure 6th Mill	Pressure 7th Mill	Tons Cane per Hour	Tonnage Ratio
H. C. & S. Co.	6	32.7	22.5	24.7	27	30	....	....	....	300	410	430	460	550	....	....	....	96.51	1.37
"	6	32.7	22.5	24.7	27	30	....	....	....	300	410	430	460	550	....	....	....		
Oahu	20	....	29.2	25.4	22.6	25	25.7	....	....	....	252	462	390	431	431	....	....	70.74	1.83
"	20	....	19.7	17.6	20	20.7	....	....	....	....	382	323	366	339	....	....	....		1.91
Maui Agr.	21	....	23	23.5	25.2	28.8	23.5	25.2	28.8	....	450	340	350	486	260	230	380	61.46	1.74
Ewa	5	....	17.9	16.7	19	20.4	24.2	27.7	31.6	....	322	415	369	428	430	424	419	66.22	1.34
Pioneer	10	45.1	30.6	25.1	29.8	32.9	....	....	....	....	500	400	380	425	....	....	....	56.29	1.88
Waialua	17	....	25.4	23.8	20.2	22.9	24.7	....	....	....	300	420	420	420	450	....	....	51.3	1.46
Haw. Sug.	16	....	14.2	16.3	18.6	18.6	....	....	....	250	520	400	408	408	....	....	....	41.34	1.17
Olaa	36	....	20	22	25	29	....	....	....	....	400	400	380	410	....	....	....	49.64	1.76
Honolulu	13	....	20.6	19.7	22.1	24.1	....	....	....	....	250	500	450	450	....	....	....	38.43	1.36
Onomea	34	29.9	23.4	23.4	24.3	30.1	....	....	....	....	400	370	370	400	....	....	....	39.29	1.56
Kekaha	25	17	14.2	16	17.2	....	....	....	....	....	335	357	366	....	....	....	....	26.78	1.61
Hakalau	7	....	23	25.5	28.2	16.3	....	....	....	....	322	322	345	380	....	....	....	32.47	1.56
Hilo	33	28.6	18.8	21.8	22.6	12	....	....	....	....	395	395	395	430	....	....	....	34.00	1.35
McBryde	12	....	17.9	18.2	20.1	....	....	....	....	....	452	490	502	....	....	....	....	37.63	1.54
Wailuku	2	24	19	11	13	15	....	....	....	....	440	365	365	420	....	....	....	33.47	0.95
Haw. Agr.	30	21.3	19.7	20.3	22.5	24	....	....	....	356	366	360	370	470	....	....	....	45.42	1.80
Lihue	27	28	20	20	19.6	22	....	....	....	....	470	400	430	445	....	....	....	43.94	1.25
Waiakea	3	....	....	....	....	....	....	....	....	....	....	328	313	334	....	....	....	27.18	1.63
Honokaa	35	....	23.4	16.8	22	24.7	27.5	....	....	....	....	400	400	400	400	....	....	36.28	1.44
Laupahoehoe	41	....	23	21.7	18.8	20.5	....	....	....	....	266	349	319	334	....	....	....	23.72	1.42
Makee	14	....	17.7	20.2	23.2	....	....	....	....	....	380	440	400	....	....	....	....	40.51	2.25
Lihue, Han.	46	16	16.7	19.2	21.8	....	....	....	....	....	435	420	420	....	....	....	....	36.57	1.29
Kahuku	43	11.2	6.9	7.8	9	....	....	....	....	182	528	390	469	....	....	....	....	20.69	0.86
Pepeekeo	19	31.4	17.9	19.7	21.6	....	....	....	....	....	375	375	375	....	....	....	....	22.47	1.35
Paauhau	24	27.4	17.4	21.2	23.5	25.8	....	....	....	....	414	309	337	374	....	....	....	29.68	1.18
Koloa	38	22.1	16.6	18.3	15.1	16.7	....	....	....	....	400	400	400	400	....	....	....	31.16	1.24
Honomu	37	21.2	16.9	19.4	21.6	....	....	....	....	....	400	400	400	....	....	....	....	22.11	1.33
Hawi	26	19.5	22	18	20	20	....	....	....	148	140	280	280	300	....	....	....	35.71	1.32
"	26	....	18	20	20	....	....	....	....	....	280	280	288	....	....	....	....		
Hamakua	15	26	18	19	22	....	....	....	....	....	296	296	305	....	....	....	....	24.10	1.44
Hutchinson	31	....	17.9	19.9	21.9	....	....	....	....	....	344	386	336	....	....	....	....	26.37	1.58
Kaeleku	47	....	....	16.3	17.1	19.4	....	....	....	....	....	329	346	354	....	....	....	25.99	1.56
Kaiwiki	32	....	....	16.1	17.9	19.9	....	....	....	....	....	337	337	328	....	....	....	22.49	1.35
Kilauea	23	19	19.5	20.5	20.5	....	....	....	....	320	320	300	312	....	....	....	....	24.39	1.46
Kohala	40	....	21	16	18	22	....	....	....	....	....	276	325	383	....	....	....	26.41	1.59
Waianae	9	....	15.2	15.2	15.2	15.7	....	....	....	....	288	290	293	347	....	....	....	24.60	1.48
Waimanalo	1	....	15.5	15.5	15	....	....	....	....	....	....	260	....	....	....	....	....	17.60	1.74
Niulii	39	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	14.40	1.42
Halawa	29	24	20	20	....	....	....	....	....	175	180	231	....	....	....	....	....	13.84	1.59
Olowalu	18	19.5	18.7	25.5	25.5	....	....	....	....	214	214	212	212	....	....	....	....	15.25	1.43
Waimea	4	....	....	....	....	....	....	....	....	....	215	....	156	156	....	....	....	15.28	1.5
Kipahulu	44	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	11.50	2.12

* 6th mill opening 1/16x0, 7th mill opening 1/16x0. Returner bar clearance—center, 7th mill 1 3/8.

† 6th mill opening 7/8x0, 7th mill opening 1/2x0. Returner bar clearance 6th mill 1 1/2, 1 3/4, 2; 7th mill 1 1/4, 1 1/2, 1 3/4.

CANE MILL DATA, SEASON OF 1919 (CONTINUED)

ROLLER GROOVING

SURFACE GROOVES PER INCH. TOP, FRONT, BACK.

Factory	Factory No.	Milling Plant	Crusher	1st Mill	2nd Mill	3rd Mill	4th Mill	5th Mill	6th Mill	7th Mill
H. C. & S. Co.	6	K(2),2RC78,S72,12RM78	— —	1 1/3, 1 1/3, 1 1/3	8, 1 1/3, 8	8, 1 1/3, 8	8, 1 1/3, 8	....	....	....
"	6	K(2),2RC78,S72,12RM78	— —	1 1/3, 1 1/3, 1 1/3	8, 1 1/3, 8	8, 1 1/3, 8	8, 1 1/3, 8	....	....	....
Oahu	20	K(2),S72,14RM78	....	4/5, 4/5	2 1/2, 2 1/2, 2 1/2	2 1/2, 2 1/2, 2 1/2	2 1/2, 2 1/2, 2 1/2	2 1/2, 2 1/2, 2 1/2	....	....
"	20	K(2),12RM78	....	2, 2/3, 2/3	2 1/2, 2 1/2, 2 1/2	2 1/2, 2 1/2, 2 1/2	7, 7, 7	....	....	....
Maui Agr.	21	K(2),21RM66	....	— — —	— — —	— — —	— — —	— — —	— — —	— — —
Ewa	5	K(2),20RM78	....	1, 1	2 2/3, 1 4/5, 2	2 2/3, 1 1/2, 2 2/3	2 2/3, 1 1/2, 2 2/3	1 4/5. 1, 2	2 2/3, 1 1/2, 2 2/3	2 2/3, 1 1/2, 2 2/3
Pioneer	10	K,2RC60,S54,12RM72	— —	7, 7, 7	7, 7, 7	7, 7, 7	7, 7, 7	....	....	....
Waialua	17	K(2),14RM78	....	4/5, 4/5	1 1/3, 1 1/3, 1 1/3	2 2/3, 2 2/3, 2 2/3	2 2/3, 2 2/3, 2 2/3	2 2/3, 2 2/3, 2 2/3	....	....
Haw. Sug.	16	K,2RC72,S72,12RM78	— —	3/4, 4, 6	4, 4, 6	4, 6, 6	4, 4, 6	....	....	....
Olaa	36	K,S72,12RM78	....	2, 6, 6	6, 6, 6	6, 6, 6	6, 6, 6	....	....	....
Honolulu	13	K(2),S54,11RM78	....	2/3, 2/3	1 1/3, 3, 1 1/3	6, 3, 6	6, 3, 6	....	....	....
Onomea	34	2RC60,S54,12RM66	— —	7, 4, 7	7, 4, 7	7, 4, 7	7, 4, 7	....	....	....
Kekaha	25	2RC54,9RM60	— —	8/9, 8/9, 8/9	7, 7, 7	7, 7, 7	....	....	....	....
Hakalau	7	2RC54,12RM9-60,3-66	— —	5, 5, 5	7, 7, 7	7, 7, 7	7, 7, 7	....	....	....
Hilo	33	K,2RC60,12RM66	— —	2 1/2, 5, 5	5, 5, 5	5, 5, 5	5, 5, 5	....	....	....
McBryde	12	K,S54,9RM84	....	6, 6, 6	6, 6, 6	6, 6, 6	....	....	....	....
Wailuku	2	K,2RC72,12RM78	— —	2 1/2, 1 1/4, 2 1/2	4, 4, 4	4, 4, 4	4, 4, 4	....	....	....
Haw. Agr.	30	3RC60,12RM66	2/3, 2/3, 2/3	2, 5, 2	5, 5, 5	5, 5, 5	5, 4, 5	....	....	....
Lihue	27	K,2RC72,12RM78	— —	2 2/3, 2 2/3, 5	5, 4, 5	5, 5, 0	5, 5, 0	....	....	....
Waiakea	3	K(2),S42,11RM60	....	— —	4 1/2, 4, 4	4 1/2, 4, 4	4 1/2, 4, 4	....	....	....
Honokaa	35	K(2),14RM2-60,12-66	....	— —	2 2/3, 2 2/3, 2 2/3	5, 2 1/2, 4	7, 5, 5	7, 7, 7	....	....
Laupahoehoe	41	K(2),11RM60	....	2/3, 2/3	7, 7, 7	6, 6, 6	7, 7, 7	....	....	....
Makee	14	K(2),9RM72	....	1, 3, 1	1, 7, 7	3, 7, 7	....	....	....	....
Lihue, Han.	46	K,2RC72,9RM78	— —	6, 2, 0	7, 3 1/2, 0	5, 3 1/2, 0	....	....	....	....
Kahuku	43	3RC60,S54,9RM72	— — —	4, 4, 7	7, 7, 7	7, 7, 7	....	....	....	....
Pepeekeo	19	2RC54,9RM60	— —	5, 7, 0	5, 5, 0	5, 7, 0	....	....	....	....
Paauhau	24	2RC60,12RM66	— —	4, 4, 4	7, 7, 7	7, 7, 7	7, 7, 7	....	....	....
Koloa	38	K,2RC60,12RM66	— —	2 2/3, 2 2/3, 2 2/3	5 1/3, 2 2/3, 5 1/3	5 1/3, 2 2/3, 5 1/3	5 1/3, 2 2/3, 5 1/3	....	....	....
Honomu	37	2RC60,9RM60	2/3, 2/3	6, 5, 0	5, 5, 5	6, 6, 6	....	....	....	....
Hawi	26	K,3RC48,12RM3-48,9-54	3 1/2, 1, 3 1/2	3, 3 1/2, 3 1/2	3, 1 1/3, 3	3, 1, 3	3 1/2, 1 1/3, 3 1/2	....	....	....
"	26	K(2),S42,9RM54	....	3 1/2, 1, 2	3 1/2, 1 1/3, 3	4, 3 1/2, 4	....	....	....	....
Hamakua	15	K,2RC60,9RM60	— —	6, 4, 4	6, 4, 6	7, 6, 7	....	....	....	....
Hutchinson	31	2RC60,9RM60	2/3, 2/3	5, 5, 5	5, 5, 5	5, 5, 5	....	....	....	....
Kaeleku	47	K(2),11RM2-54,9-60	....	— —	3, 5, 3	5, 5, 0	5, 5, 0	....	....	....
Kaiwiki	32	K(2),11RM60	....	— —	3, 3, 6	6, 3, 6	6, 3, 6	....	....	....
Kilauea	23	K,S,3RC60,9RM60	8/9, 8/9, 8/9	4, 4, 0	7, 4, 0	7, 4, 0	....	....	....	....
Kohala	40	K(2),S42,11RM60	....	1 1/3, 1 1/3	2 1/2, 2 1/2, 2 1/2	2 1/2, 3 1/2, 3 1/2	4, 4, 4	....	....	....
Waianae	9	K,12RM60	....	5, 7, 7	7, 7, 7	7, 7, 7	7, 7, 7	....	....	....
Waimanalo	1	K,8RM6-54,2-60	....	3, 2, 3	4, 4, 4	4, 4	....	....	....	....
Niulii	39	K(2),9RM54	....	— — —	— — —	— — —	....	....	....	....
Halawa	29	K,2RC60,6RM50	— —	4, 4, 4	4, 4, 4	....	....	....	....	....
Olowalu	18	K,3RC48,9RM48	3/4, 3/4, 3/4	5, 5, 5	5, 5, 5	5, 5, 5	....	....	....	....
Waimea	4	2RC48,12RM42	— —	8/9, 8/9, 8/9	4, 4, 8	8, 4, 8	8, 4, 8	....	....	....
Kipahulu	44	K,5RM3-42,2-54	....	5, 5, 1	5, 5	....	....	....	....	....

JUICE GROOVES

1st Mill and 2nd Mill

Factory No.	1st Front Width	1st Front Depth	1st Front Pitch	1st Back Width	1st Back Depth	1st Back Pitch	2nd Front Width	2nd Front Depth	2nd Front Pitch	2nd Back Width	2nd Back Depth	2nd Back Pitch
6	3/16	2	2 1/4	—	—	—	3/16	2	3	1/4	1 3/4	2
6	3/16	2	2 1/4	—	—	—	3/16	2	3	1/4	1 3/4	2
20	—	—	—	....	....	....	5/16	2	3 1/2	5/16	2	3 1/2
20	1/2	2	3	1/2	2	—	1/2	2	2 1/2	1/2	2	4
21	—	—	—	—	—	—	—	—	—	—	—	—
5	—	—	—	....	....	....	—	—	—	1/4	1	4
10	3/16	1 5/8	4	3/16	1 5/8	2 1/4	3/16	1 5/8	4	3/16	1 5/8	4
17	—	—	—	....	....	....	1/4	1 3/4	3	1/4	1 3/4	4 1/2
16	1/4	2	2	1/8	1 1/4	2	1/4	2	2	1/8	1 1/4	2
36	3/16	1 1/2	3	3/16	1 1/2	3	3/16	1 1/2	3	3/16	1 1/2	3
13	—	—	—	....	....	....	1/4	1 1/8	1 1/2	—	—	—
34	3/16	1 3/4	2	5/32	1 1/4	2	3/16	1 3/4	2	5/32	1 1/4	2
25	—	—	—	—	—	—	5/16	1 1/4	2 1/2	1/8	1 1/4	2
7	1/4	1 1/2	4	1/8	1 1/2	2	1/4	1 1/2	2	1/8	1 1/2	2
33	1/4	2	2 1/2	1/8	1 3/8	1 3/5	1/4	2	3	1/8	1 3/8	1 3/5
12	3/8	1 5/16	3	5/16	1 1/8	2 1/4	3/8	1 1/2	3	1/4	1 1/4	2 1/4
2	—	—	—	—	—	—	7/16	1 7/8	4	1/4	1 3/4	2
30	1/4	1 1/2	2	—	—	—	1/4	1 1/2	2	1/4	1 1/2	2
27	—	—	—	1/8	1 1/4	2 1/4	1/4	1 1/4	2 3/4	1/8	1 1/4	2 1/2
3	—	—	—	....	....	....	1/4	1 3/4	3	1/4	1 3/4	2
35	—	—	—	....	....	....	1/4	1 1/2	2	—	—	—
41	—	—	—	....	....	....	1/4	1 1/2	3	1/8	1 1/2	2 1/2
14	1/4	1 1/2	4	—	—	—	1/4	1 1/2	4	1/4	1 1/2	2
46	1/4	1 1/4	2 1/2	1/8	1	2	1/4	1 1/4	2 1/2	1/8	1	2
43	1/4	1	4 1/4	—	—	—	1/4	1 1/8	4	—	—	—
19	1/4	1 1/4	3	1/8	1 1/2	1 1/2	1/4	1 1/4	3	1/8	1 1/2	1 1/2
24	9/32	1 1/2	3	9/64	1 1/4	2	9/32	1 1/2	3	9/32	1 1/4	3
38	1/4	1 1/8	2 5/8	1/8	1	2 5/8	1/4	1 1/8	2 5/8	1/8	1	2 5/8
37	1/4	1 1/2	3	1/4	1 1/2	3	1/4	1 1/2	3	1/4	1 1/2	2
26	—	—	—	—	—	—	—	—	—	—	—	—
26	—	—	—	—	—	—	—	—	—	—	—	—
15	3/8	1 1/2	1 5/8	—	—	—	3/8	1 1/2	3	1/4	1 1/2	1 3/4
31	1/4	1 1/4	3	1/8	1 1/4	2	1/4	1 1/4	3	1/8	1 1/4	2
47	—	—	—	....	....	....	1/4	1 1/2	2	1/8	1 1/2	2
32	—	—	—	....	....	....	3/8	1 1/4	2 3/4	—	—	—
23	5/16	1 1/4	3	3/16	1 1/4	2	5/16	1 1/4	3	3/16	1 3/8	2
40	—	—	—	....	....	....	1/4	1	2 1/2	1/4	1	2 3/4
9	—	—	—	—	—	—	—	—	—	—	—	—
1	—	—	—	—	—	—	1/2	7/8	3	—	—	—
39	—	—	—	—	—	—	—	—	—	—	—	—
29	1/4	1 1/2	2	1/8	1 1/2	2	1/4	1 1/2	2	1/8	1 1/2	2
18	1/8	1 1/4	2	1/8	1 1/4	2	1/8	1 1/4	2	1/8	1 1/4	2
4	—	—	—	—	—	—	1/4	1	2	1/8	1	2
44	—	—	—	1/4	1	1	1/4	1 1/4	1 3/4	....	....	....

3rd Mill and 4th Mill

Factory No.	3rd Front Width	3rd Front Depth	3rd Front Pitch	3rd Back Width	3rd Back Depth	3rd Back Pitch	4th Front Width	4th Front Depth	4th Front Pitch	4th Back Width	4th Back Depth	4th Back Pitch
6	3/16	2	3	1/4	1 3/4	4	3/16	2	3	1/4	1 3/4	4
6	3/16	2	3	1/4	1 3/4	4	3/16	2	3	1/4	1 3/4	4
20	5/16	2	3 1/2	5/16	2	3 1/2	5/16	2	3 1/2	5/16	2	3 1/2
20	5/16	2	3 1/2	1/2	2	3 1/2	1/4	2	3 1/2	1/4	2	4
21	—	—	—	—	—	—	—	—	—	—	—	—
5	—	—	—	1/8	1 1/8	3 1/2	—	—	—	1/8	1 1/4	3 1/2
10	3/16	1 5/8	4	3/16	1 5/8	4	3/16	1 5/8	4	3/16	1 5/8	3
17	5/16	1 3/4	2	5/16	1 3/4	2	3/16	1 3/4	2	3/8	1 3/4	2 1/2
16	1/4	2	2	1/8	1 1/4	2	1/4	2	2	1/8	1 1/4	2
36	3/16	1 1/2	3	3/16	1 1/2	3	3/16	1 1/2	3	3/16	1 1/2	3
13	1/4	1 1/4	1 1/2	3/16	1	1 1/2	3/16	1 1/8	1 3/4	3/16	1	1 1/2
34	3/16	1 3/4	2	5/32	1 1/4	2	3/16	1 3/4	2	5/32	1 1/4	2
25	5/16	1 1/4	2 1/2	1/8	1 1/4	1 3/4	....	....	....	....	....	....
7	1/4	1 1/2	4	1/8	1 1/2	2	1/4	1 1/2	2	1/8	1 1/2	2
33	1/4	2	3	1/8	1 3/8	1 3/5	1/4	2	3	1/8	1 3/8	1 3/5
12	5/16	1 3/8	3	1/4	1 1/4	2 1/4	....	....	....	....	....	....
2	3/8	1 3/4	4	1/4	1 3/8	2	1/4	1 13/16	2	3/16	1 7/16	2
30	1/4	1 1/2	2	3/16	1 1/2	2	5/16	1 1/2	2	1/8	1 1/2	2
27	1/4	1 1/4	2 1/2	1/8	1 1/4	2 1/2	1/8	1 1/4	3	1/8	1	2 1/4
3	1/4	1 3/4	3	1/4	1 3/4	2	1/4	1 3/4	3	1/4	1 3/4	2
35	3/8	1 1/2	2	1/4	1 1/2	2	1/4	1 1/2	2	3/16	1 1/2	2
41	1/4	1 1/2	3	1/8	1 1/2	2	1/4	1 1/2	3	1/8	1 1/2	2
14	1/4	1 1/2	4	1/4	1 1/2	2	....	....	....	....	....	....
46	1/4	1 1/4	2 1/2	1/8	1	2	....	....	....	....	....	....
43	1/4	1 1/4	4	—	—	—	....	....	....	....	....	....
19	1/4	1 1/4	3	1/8	1 3/4	1 1/2	....	....	....	....	....	....
24	9/64	1 1/4	2	9/64	1 1/4	2	9/32	1 1/2	3	9/64	1 1/4	2
38	1/4	1 1/8	2 5/8	1/8	1	2 5/8	1/4	1 1/8	2 5/8	1/8	1	2 5/8
37	5/32	1 1/2	2	5/32	1 1/2	2	....	....	....	....	....	....
26	—	—	—	—	—	—	—	—	—	1/4	1 1/2	3
26	1/4	1 1/2	3	1/4	1 1/2	3	....	....	....	....	....	....
15	1/4	1 1/2	3	3/16	1 1/2	2	....	....	....	....	....	....
31	1/8	1 1/4	2	1/8	1 1/4	2	....	....	....	....	....	....
47	1/4	1 1/2	2	1/8	1 1/2	2	1/4	1 1/2	3	1/8	1 1/2	2
32	3/8	1 1/4	2 3/4	3/16	1 1/4	2 3/8	3/8	1 1/4	2 3/4	3/16	1 1/4	2 3/8
23	5/16	1 1/4	3	3/16	1 1/4	2	....	....	....	....	....	....
40	1/4	1	2 1/2	1/4	1	3	1/4	2	3	1/4	2	3
9	1/4	1 1/4	2 1/2	—	—	—	1/4	1 1/4	2 3/8	1/8	1 1/4	3
1	1/2	7/8	3	....	....	....	....	....	....	....	....	....
39	—	—	—	—	—	—	....	....	....	....	....	....
29	....	....	....	....	....	....	....	....	....	....	....	....
18	1/8	1 1/4	2	1/8	1 1/4	2	....	....	....	....	....	....
4	1/4	1	2	1/8	1	2	1/4	1	2	1/8	1	2
44	....	....	....	....	....	....	....	....	....	....	....	....

5th Mill, 6th Mill and 7th Mill

Factory No.	5th Front Width	5th Front Depth	5th Front Pitch	5th Back Width	5th Back Depth	5th Back Pitch	6th Front Width	6th Front Depth	6th Front Pitch	6th Back Width	6th Back Depth	6th Back Pitch	7th Front Width	7th Front Depth	7th Front Pitch	7th Back Width	7th Back Depth	7th Back Pitch	Factory
6	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	H. C. & S. Co.
6	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	"
20	1/4	2	2	1/4	2	1 3/4	....	....	....	....	....	....	....	....	....	....	....	....	Oahu
20	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	"
21	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	Maui Agr.
5	—	—	—	1/8	1	4	1/4	1 1/2	3 1/2	1/8	1	3 1/2	1/4	1 1/2	4	1/8	1	3 1/2	Ewa
10	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	Pioneer
17	3/16	1 3/4	2 1/2	3/16	1 3/4	2 1/2	....	....	....	....	....	....	....	....	....	....	....	....	Waialua
16	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	Haw. Sug.
36	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	Olaa
13	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	Honolulu
34	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	Onomea
25	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	Kekaha
7	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	Hakalau
33	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	Hilo
12	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	McBryde
2	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	Wailuku
30	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	Haw. Agr.
27	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	Lihue
3	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	Waiakea
35	5/32	1 1/2	2	5/32	1 1/2	2	....	....	....	....	....	....	....	....	....	....	....	....	Honokaa
41	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	Laupahoehoe
14	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	Makee
46	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	Lihue, Han.
43	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	Kahuku
19	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	Pepeekeo
24	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	Paauhau
38	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	Koloa
37	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	Honomu
26	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	Hawi
26	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	"
15	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	Hamakua
31	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	Hutchinson
47	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	Kaeleku
32	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	Kaiwiki
23	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	Kilauea
40	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	Kohala
9	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	Waianae
1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	Waimanalo
39	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	Niulii
29	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	Halawa
18	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	Olowalu
4	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	Waimea
44	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	Kipahulu